Early symptoms assessment as indicator to control Grapevine Powdery Mildew with reduced fungicide applications

P. Cartolaro[a], L. Delière[a], L. Delbac[a], O. Naud[b], A. Calonnec[a]

[a]INRA-Bordeaux UMR INRA-ENITA 1065 Santé Végétale – ISVV, BP81, 33883 Villenave d'Ornon – France, e-mail cartolaro@bordeaux.inra.fr, [b] Cemagref – UMR ITAP, BP 5095, 34196 Montpellier Cedex 5 – France.

In French vineyards, epidemics of powdery mildew *(Erisyphe necator)* occur with a high variability within years and places. Damage caused by the disease can be severe as in 2004 in Bordeaux on Merlot cultivar or in Champagne and Burgundy on Chardonnay. Except in the South region and mainly on Carignan cultivar, flagshoots are rarely or never observed in most of the French vineyards, and therefore are not responsible for the initiation of epidemics. Conversely, cleistothecia are frequently observed on leaves after harvest and ascospores can be released at spring as described in several countries (Cortesi *et al.*, 1997, Gadoury *et al.*, 1988. Jailloux *et al.*, 1998, Pearson and Gadoury 1987). Primary symptoms are observed on leaves located first or second rank from the base of shoots, near the bark of the trunks (photo). Moreover, early foci cause higher epidemic development on leaves and greatest damage on bunches (Calonnec *et al.*, 2006)

No forecast model is actually useful in France to drive strategies of protection (except in flagshoot cases in the South where initiation of the disease is well known) and usual preventive management is based on growth stages of the vine. Therefore, early detection of symptoms seems the actual most appropriate way to validate the presence of early disease.

Our study conducted from 2003 to 2009 in commercial vineyard conditions, had the objective to evaluate powdery mildew [pm] decision rules based on: (i) incidence disease assessments early in the season, giving so the starting time of the epidemic; (ii) a few number of well-timed fungicide applications according to the critical times of the epidemics development (increase phase of disease incidence on leaves before flowering and highest risk period for young berries infection at flowering) (Gadoury *et al.*, 2003).

Material and methods

The study is conducted in two steps. A preliminary experimentation had been realised in the Bordeaux vineyard from 2003 to 2007, to adjust and validate the decision rules. Since 2008, the experiment is conducted within national network in collaboration with extension services and vinegrowers.

Description of the pm rules

- A first pm rule applied in 2003 and 2004 was based on two systematic treatments, at flowering stage (BBCH-67) (T3) and 14 days later (around BBCH-75) (T4), and two optional treatments depending on the results of two disease assessments: first one (T2) at pre-flowering stage (BBCH-57) if I_1>5% and second one (T5) at bunch closure (BBCH-77) if I_2>10% (Table 1). Following this rule, a minimum of 2 treatments up to 4 can be applied.

Table 1: Description of the decision rule applied in 2003 and 2004

Growth stage[(a)]	Indicator			Fungicide application	
	Type	Sampling: plants	Sampling: organs/plant	Type	Condition
15/17	I_1 incidence of dis. plants	1/10	4 leaves[(b)]	-	-
57	-	-	-	Optional (T2)	I_1 >5%
67	-	-	-	**Systematic (T3)**	-
75	-	-	-	**systematic[(c)] (T4)**	-
77	I_2 incidence of dis. bunches	1/10	5 bunches	Optional (T5)	I_2 >10%

(a) according to BBCH scale **(b)** located on 1st or 2nd rank from the base of the shoot
(c) 14 days after the previous application

Table 2: Description of the decision rule applied from 2005.

Growth stage[(a)]	Indicator			Fungicide application	
	Type	Sampling: plants	Sampling: organs/plant	Type	Condition
15/17	I_{1a} incidence of dis. plants	1/10	4 leaves[(b)]	**Systematic (T1)**	-
57	I_{1b} incidence of dis. plants	1/10	6 leaves[(c)]	Optional (T2)	I_{1b} >10%
67	-	-	-	**Systematic (T3)**	-
75	-	-	-	Optional[(d)] (T4)	I_{1a} > 2% or I_{1b} >10%
77	I_2 incidence of dis. bunches	1/10	5 bunches	Optional (T5)	I_2 >20%

(a) according to BBCH scale **(b)** located on 1st or 2nd rank from the base of the shoot
(c) located on 4th to 7th rank from the base of the shoot **(d)** 14 days > previous spray

- In 2005, the pm rule was modified to improve the control of the disease mainly in the early phase of the epidemic development: the first systematic treatment being applied earlier at pre-flowering stage (BBCH 15/17) (T1) and the second one at flowering (T3) (Table 2). A second assessment I_{1b} was added at stage BBCH 57. Thus, an optional treatment (T2) could be applied before flowering in case of high level of disease assessed on leaves (I_{1b}>10%) around two weeks after the first assessment and treatment. A second one (T4), after flowering, was applied at stage 75 [BBCH scale] depending on the level of disease at pre-flowering (I_{1a}>2% or I_{1b}>10%), and the last treatment (T5) at bunch closure if more than 20% of the bunches were diseased at

stage 77 (third and last decisional assessment I_2). Thus, according to this pm rule, a minimum of 2 treatments can be applied in case of none or low disease level, up to 5 if high level of disease is assessed in the parcel.

Experimental design

- Commercial parcels of 0.25 to 2 ha, without replicates and untreated plots, under natural disease infections.
- Disease assessments are realised in a central area of the parcel of 1000 plants (whatever the size of the parcel and planting density), on each site:
  - to evaluate decisional indicators, the frequency of diseased plants on leaves or diseased clusters is assessed over 100 plants (10% sampled);
  - to evaluate the strategy efficacy, the average severity of all the bunches of 30 sampled plants is assessed at pre-harvest stage (beginning of colour change).
- Fungicides applied are chosen indifferently among DMI and Strobilurin groups and all treatments are performed by the growers with their usual equipments.
- Sites and vine cultivars. Since 2003, the experiment is conducted in INRA commercial vineyards near Bordeaux, in 2 sites (Latresne – Cadaujac) with different disease history, less than 10 km away from one another, both on merlot and cabernet-sauvignon cultivars. In 2007, three parcels of private vineyards were added, on merlot (2 sites) and cabernet-franc (1 site). Since 2008, experiment is extended within national network including South and further East regions of the French vineyards with local representative cultivars: 22 parcels in 2008 and 37 in 2009 (Table 3).

Table 3: Number and geographical repartition of parcels and cultivars where the powdery mildew decisions rules are applied from 2003 to 2009.

	Year	Region	Vineyard	Cultivars (nb of sites)	Total parcels
Preliminary study (1st rule)	2003	West	Bordeaux	Merlot (2)	2
	2004			Merlot (2)	2
	2005	West	Bordeaux	Merlot (2) Cab-Sauvignon (2)	4
	2006	West	Bordeaux	Merlot (2) Cab-Sauvignon (2)	4
	2007	West	Bordeaux	Merlot (4) Cab-Sauvignon (2) Cab-Franc (1)	7
National network	2008	West	Bordeaux	Merlot (8) Cab-Sauvignon (3) Cab-Franc (1)	12
		South	Languedoc-Roussillon	Carignan (3) Syrah (2) Mourvedre (1) Merlot (3) Chardonnay (1)	10
	2009	West	Bordeaux	Merlot (10) Cab-Sauvignon (4) Cab-Franc (1) Semillon (1)	17
			Cognac	Ugni blanc (1)	
		South	Languedoc-Roussillon & Côtes du Rhône	Carignan (4) Syrah (1) Mourvedre (1) Grenache (2) Merlot (3) Chardonnay (1)	12
		East	Beaujolais & Mâconnais	Gamay (4) Chardonnay (2)	8
			Jura	Trousseau (1)	
			Champagne	Pinot noir (1)	

Results

Preliminary study from 2003 to 2007

- *First pm decision rule.*

In the Bordeaux vineyards, powdery mildew epidemics were moderate in 2003 and much higher in 2004, with high variability between sites. In the Cadaujac merlot parcel, none symptom was observed on leaves at early stage first year (I_{1a} assessment) as well as at closure stage on bunches. According to the first rule, only the 2 systematic treatments were applied at flowering (T3, T4), providing well protected berries at harvest (Table 4). On the other hand, near of 20% of plants showed early symptoms in Latresne merlot parcel, triggering the first optional treatment at pre-flowering (T1). With the 2 systematic treatments, this strategy achieved good control of the disease.

In 2004, 2% of diseased plants were assessed at I_{1a} in the Cadaujac parcel, and T1 treatment was not triggered. The two systematic treatments at flowering didn't achieve control of berries infection and the optional treatment T5 was applied at closure after the I_2 assessment on bunches (35%). This gave satisfactory protection at harvest with 0.4% severity of powdery mildew on bunches in spite of 21.6% disease incidence (one or two infected berries / diseased bunch). In Latresne parcel, higher powdery mildew epidemic was observed; I_{1a} and I_2 indicators showed 23.5% and 70.4% disease incidence, respectively on plants (leaves) and on bunches. The full 4 treatments program applied resulted in 63% incidence and 2.3% severity which is at the limit of acceptability. These results showed that pre-flowering control of the disease on leaves have to be reinforced to assure better control of berries infection at flowering in case of high epidemic.

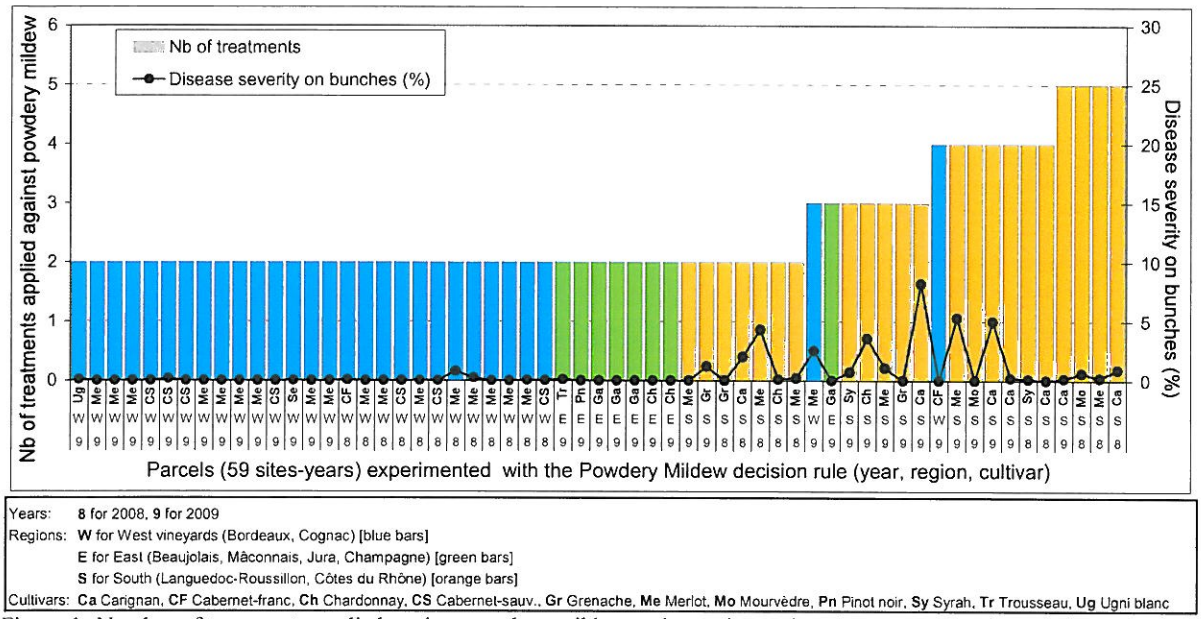
- *Second pm decision rule.*

In 2005, the second rule was applied in Cadaujac and Latresne sites, in merlot and cabernet-sauvignon parcels. Epidemic level was generally lower than the previous year in the Bordeaux vineyard. In Cadaujac site where early disease level was low, grapes were well protected (<0.1% severity on bunches) applying 2 treatments (T1-T3), on both the merlot and cabernet–sauvignon parcels. In Latresne site, early disease level was higher, mainly in the merlot parcel (I_{1a} = 14.4%). Despite systematic treatment T1 applied, powdery mildew continued increasing on leaves (I_{1b} = 26.8%) triggering the two optional treatments T2 and T4. With the systematic treatment T3 applied, this led to reduce berries infection under the 20% incidence threshold of I_2, without T5 treatment application. This strategy achieved satisfactory protection with 0.6% severity on bunches at harvest. Again, successful powdery mildew control was achieved in cabernet-sauvignon parcel with 2 systematic treatments T1-T3.

In 2006, and further in 2007, powdery mildew level was lower. The two treatments program (T1-T3) was successfully applied in all the experimented parcels, except for Latresne merlot parcel where respectively 4 and 3 treatments were realised according to the presence of early symptoms. In 2007, the second disease assessment (I_{1b}=7.4%) was under the 10% threshold to trigger the T2 treatment, leading to 2.7% severity at harvest. It seems that it would have been useful to apply this treatment to achieve good final control as reached in 2006.

Table 4: decisional indicators values, treatments applied and disease assessment at harvest (incidence and severity) on bunches.

year	disease level in vineyards	site	cultivar	decision rule applied	disease level indicators: on leaves before flowering (% of plants diseased) I1a	I1b	disease level indicators: on bunches before closure (% of bunches dis.) I2	fungicide treatments T1	T2	T3	T4	T5	Total Nb	bunches infestation at harvest: Incidence	Severity
2003	-/+	Cadaujac	merlot	1st	0.0%		0.0%			X	X		2	0.003%	< 0.1%
		Latresne	merlot	1st	19.9%		0.9%	X		X	X		3	1.1%	< 0.1%
2004	++	Cadaujac	merlot	1st	2.0%		35.0%			X	X	X	3	**21.6%**	0.4%
		Latresne	merlot	1st	23.5%		70.4%	X		X	X	X	4	**62.9%**	2.3%
2005	-/+	Cadaujac	merlot	2nd	0.6%	1.2%	0.4%	X		X			2	1.4%	< 0.1%
			cab-sauv.	2nd	0.0%	0.0%	0.9%	X		X			2		< 0.1%
		Latresne	merlot	2nd	14.4%	26.8%	18.0%	X	X	X	X		4	**21.0%**	0.6%
			cab-sauv.	2nd	0.8%	3.5%	0.6%	X		X			2		< 0.1%
2006	-/+	Cadaujac	merlot	2nd	0.0%	0.6%	1.40%	X		X			2		0.1%
			cab-sauv.	2nd	0.0%	0.0%	0.90%	X		X			2		< 0.1%
		Latresne	merlot	2nd	2.6%	12.4%	7.30%	X	X	X	X		4		0.4%
			cab-sauv.	2nd	0.0%	2.5%	0.60%	X		X			2		< 0.1%
2007	-	Cadaujac	merlot	2nd	0.0%	0.0%	0.0%	X		X			2		0%
			cab-sauv.	2nd	0.0%	0.0%	0.0%	X		X			2		0%
		Latresne	merlot	2nd	2.9%	7.4%	7.9%	X		X	X		3		2.7%
			cab-sauv.	2nd	1.4%	1.4%	1.8%	X		X			2		0.2%
		Landerrouat	merlot	2nd	0.0%	0.0%	0.0%	X		X			2	0.0%	0.0%
		Mauriac	merlot	2nd	0.0%	0.0%	0.0%	X		X			2	0.0%	0.0%
		Monsegur	cab-franc	2nd	0.0%	0.0%	0.0%	X		X			2	0.0%	0.0%



Years: 8 for 2008, 9 for 2009
Regions: W for West vineyards (Bordeaux, Cognac) [blue bars]
E for East (Beaujolais, Mâconnais, Jura, Champagne) [green bars]
S for South (Languedoc-Roussillon, Côtes du Rhône) [orange bars]
Cultivars: Ca Carignan, CF Cabernet-franc, Ch Chardonnay, CS Cabernet-sauv., Gr Grenache, Me Merlot, Mo Mourvèdre, Pn Pinot noir, Sy Syrah, Tr Trousseau, Ug Ugni blanc

Figure 1: Number of treatments applied against powdery mildew and severity on bunches assessed at harvest in parcels within national network in 2008 and 2009.

Experiment within national network (2008-2009)

In 2008 and 2009 powdery mildew epidemics were very low in French vineyards, except for South regions mainly on Carignan cultivar. According to the disease indicators levels, only the 2 systematic treatments T1 and T3 were applied in 41 out of the 59 parcels (around 70%) experimented within the national network (Figure 1). This was the case in almost all the West and East regions sites, leading perfect level of grapes protection whatever the cultivar. However, two parcels received 3 treatments; leading to either 2.5% of disease severity on bunches at harvest (West) or no diseased berries (East), respectively. One parcel received 4 treatments without any damage (West). In the South region, higher disease levels at harvest were observed: around 30% of the parcels were sprayed 2 times (T1-T3), and 20% received 3 treatments. Half of these parcels, showed more than 1% disease severity on bunches at harvest, on Carignan, Chardonnay and Merlot cultivars. The other 50% of the parcels received 4 or 5 treatments leading good control of grapes infections except for 2 cases with 5% disease severity at harvest on Carignan and Merlot. On the very susceptible Carignan cultivar, full program with 5 treatments, at least 4, was necessary to reach successful disease control.

In all the situations, disease levels at harvest were considered acceptable by the growers in accordance with their objectives of production in quantity and quality.

In near 40 among the 59 sites experimented within the network, it was possible to compare the decision rule strategy with the vine growers practices both applied in

the same parcel. Disease control level was often better with grower program (not presented), but always with a higher number of sprays (Figure 2). According to the rule strategy, 2 to 5 fungicide applications are allowed in the season. The minimal program (T1-T3) was applied in 73% of the parcels. Under the same conditions, the growers applied 3 to 8 treatments, and more than 4 treatments in 75% of cases.

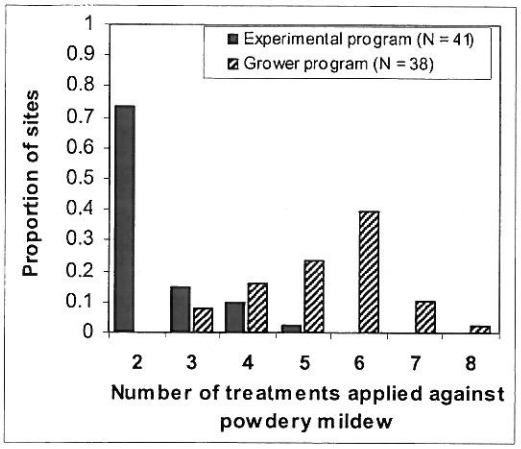


Figure 2: Distribution of vineyard parcels in number of treatments applied against powdery mildew within national network using the decisional rule (41 parcels) and vine growers practices (38 answers) during 2008 and 2009 seasons.

Conclusion

Early disease symptoms assessment can be useful as indicators to characterize powdery mildew epidemic level in grapevine parcels

Based on early disease symptoms assessment, the decision rule applied allows to reduce from 35 to 65% of treatments.

This confirm that the timing of treatments as define by the decision rule is appropriate.

Perspectives

The pm decision rule is now incorporated into a decisional process for the management of the combined protection against downy mildew and powdery mildew, called "GrapeMildews" ("Mildium" in French language), and evaluated within the national network expanded to 56 plots in 2010.

The current project, supported by the French Ministry of Agriculture, is a multidisciplinary program that combines the skills of pathologists, agronomists, economists and sociologists, within increasing national network in partnership with vinegrowers, extension services and schools of viticulture. In this program, the GrapeMildews process is taken as reference to study the technical feasibility and economic viability of input reduction and the acceptability of growers to change practices in viticulture.

Acknowledgements

This study was granted by "Agence National de la Recherche", program ADD ANR-05-PADD-001-02 and the French Ministry of Agriculture, program A2PV.

The authors would like to thank collaborators from IFV, extension services ("Chambre d'agriculture 11, 17, 33, 66, 69, 71, 84), CIVC and growers for their active participation to this program.

Literature Cited

Calonnec A, Cartolaro P, Deliere L, Chadoeuf J. 2006. Powdery mildew on grapevine: the date of primary contamination affects disease development on leaves and damage on grape. IOBC/wprs Bulletin 29: 67-73.

Cortesi P, Bisiach M, Ricciolini M, Gadoury DM. 1997. Cleistothecia of *Uncinula necator* – An additional source of inoculum in Italian vineyards. *Plant Dis.* 81:922-926.

Gadoury DM, Pearson RC. 1988. Initiation, development, dispersal, and survival of cleistothecia of *Uncinula necator* in New York vineyards. *Phytopathology* 78:1413-1421.

Gadoury D, Seem R, Ficke A, Wilcox W. 2003. Ontogenic resistance to powdery mildew in grape berries. *Phytopathology* 93:547-555.

Jailloux F, Thind T, Clerjeau M. 1998. Release, germination, and pathogenicity of ascospores of *Uncinula necator* under controlled conditions. *Can. J. Bot.* 76: 777-781.

Pearson RC, Gadoury DM. 1987. Cleistothecia, the source of primary inoculum for grape powdery mildew in New York. *Phytopathology* 77:1509-1514.