www.agrometeo.ch an interactive platform for a better management of grapevine diseases and pests

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Abstract: To control the main fungal diseases in accordance with the epidemiological development of the fungi in viticulture, the use of forecasting systems is one of the major progresses. Agrometeo is an interactive platform (www.agrometeo.ch) and a general tool for agriculture, including actual and historical weather data, modules for field crops, grapevine and fruit orchards. The grapevine module contains forecasting for downy mildew and grape berry moths; leaf area adapted spraying, growth development model, pesticides index, and descriptions of the main diseases and pests. The forecasting modules use data from a weather station network covering the whole viticulture area of Switzerland. Grapevnie downy mildew forecasting is done with Vitimeteo, a new expert-system for the forecast of grapevine downy mildew, designed by the research institute of Freiburg (Germany), Agroscope ACW and the company Geosens. The software generates graphics and tables freely available for the growers on the Internet. Leaf area adapted spraying was developed in analogy to the tree row volume concept on fruit orchards. The experiments show a reduction of about 20 to 30% of the use of pesticides by calculating the precise dose needed for a given leaf area. The module in www.agrometeo.ch allows a ready to use solution for the calculation of the amount of plant protection products based on the width and height of the leaf canopy and the row distance, depending on the registered amount indicated on the package. The number of Agrometeo users is in expansion confirming the grower's interest.

Key words: grapevine, fungal diseases, pests, forecasting, agro-meteorology, Internet access, crop adapted dosage of pesticides

Introduction

To control fungal diseases in vineyards planted with *Vitis vinifera* varieties, the regular use of fungicides against downy and powdery mildews and Botrytis gray mould is necessary to ensure yield and quality of the grapes. Growers spray fungicides from budburst until beginning of ripening at regular intervals generally independent of the disease pressure, by considering weather forecast to define the spray intervals. Using this strategy under Swiss climatic conditions, over ten fungicides can be applied. Insecticides and acaricides are nearly absent in the vineyards, mites (*Tetranychus urticae* and *Panonychus ulmi*) being controlled by predatory mites (e.g. *Typhlodromus pyri, Amblyseius andersoni*) and grape berry moths (*Lobesia botrana* and *Eupoecilia ambiguella*) by sexual confusion or Bt-based products. In organic vineyards, only copper, sulphur and few partially effective natural compounds are allowed which have to be applied more frequently than synthetic fungicides. Elicitors to reinforce natural defence mechanisms of vine are still in evaluation but do not reach the performance of chemical active ingredients. The only possible progress for a restricted use of fungicides is an accurate prediction of infections and simulation of the epidemiological development of the fungi by models. The most interesting alternative to pesticides remains the breeding and planting of resistant varieties. This second point is in contradiction with current European regulations, prohibiting so-called hybrids, the only known possibility to introduce resistance genes from other *Vitis* species in *V. vinifera*. Growers planting resistant varieties can only produce table wines and are most of the time excluded from the "appellation d'origine contôlée, AOC".

In Switzerland, the Agrometeo platform project started in 2000 with the aim to centralise weather data from microclimatic measurement units on the field. Two years later, the first data were available on the Internet (www.agrometeo.ch) and the new expert-system Vitimeteo for the forecast of grapevine downy mildew was elaborated in collaboration with the Grapevine Research Institute of Freiburg (Germany) and the company Geosens. Based on historical climatic and epidemiological data and recent results on the biology of *Plasmopara viticola*, the first tests could be performed in 2004.

This paper presents the current stage of the platform Agrometeo, the grapevine downy mildew forecasting tool Vitimeteo with corresponding field epidemiological observations, the use of the forecast for the growers, and the leaf area adapted dosage of fungicides to spray at the right moment the right dosage of plant protection products.

Material and methods

The setup of a national network of weather data at the microclimatic level started in 2000 and ended in 2002 with the Internet display of the values. During this time, different weather station available on the market were tested for their reliability, precision and compatibility under field conditions, using weather data from MeteoSwiss as reference. One year later, the first data transfer into existing models for apple scab (Rimpro, Welte) and fire blight (Maryblight) predictions were performed. In 2003, all data from field measurement of weather stations from ACW and extension services in the different Swiss cantons were daily transferred by GSM to central servers in Changins for the French and Italian parts and in Wädenswil for the German part of Switzerland.

Weather station net

150 weather stations (Campbell CR10X, Campbell CR 1000, Lufft HP-100, Lufft Opus) are measuring temperature (°C), relative humidity (%), leaf wetness duration (h) and rainfall (mm) under field conditions, covering the whole country. Ten minutes data are sent via GSM, two times a day (4-6 a.m, 4-6 p.m). .

Forecast of downy mildew

The model Vitimeteo (Bleyer et al., 2008a, 2009; Viret et al., 2005) developed by the company Geosens (Germany) in collaboration with experts from Agroscope ACW (Switzerland) and the Grapevine Research Institute of Freiburg (Germany) is used since 2005, simulating the main development steps of the epidemiology of *Plasmopara viticola* (Bleyer et al., 2008b; Viret et al., 2007). All parameters included in the model can be adjusted after experimental values by the experts. Results are presented as summarized tables and graphs for each region with the possibility to access to detailed tables containing all data from the first of January on. The predicted downy mildew risk for the next five days appears greyish on the tables, based on five days weather forecast from Meteoblue (Basel, Switzerland) for temperature, rain and relative humidity.

Growth model

The growth model after Schultz (1992) is implemented and gives information on the number of developed main leaves and the leaf surface per shoot. This parameter can be of importance for the evaluation of the newly unfolded and unprotected leaves after the last treatment.

Leaf area adapted dosage of fungicides

The leaf area adapted dosage of fungicides developed by Siegfried et al. (2007) allows a rapid calculation of the dose of plant protection products to apply, using row distance and measured high and width of the leaf canopy. An easy to use calculation is available for the growers on www.agrometeo.ch.

Internet access

All data and results of calculation are actualised twice a day (9 am and 7 pm in Changins, 10 am and 3 pm in Wädenswil) and freely available on the Internet for the growers under www.agrometeo.ch.

Field experiments

On farm field experiments have been conduced on standard vineyard of 6500 to 7000 plants per ha (1.8-2.2 x 0.8 m) at different places in the French part of Switzerland and in the experimental plots of Agroscope-ACW in Changins (VD), Leytron (VS) and Wädenswil (ZH). The experiments were conduced with the sensitive varieties cv. Chasselas, Müller-Thurgau, or Pinot noir. The control strategy against downy mildew was to wait for the first primary infection calculated by Vitimeteo and to place a contact fungicide (active ingredient folpet) at 80-90% of the incubation time or a penetrating fungicide few days after the beginning of the first secondary infection (Viret et al., 2001). Spray intervals were determined using Vitimeteo, by considering duration of efficacy of 10 days for contact fungicides and of 12 days for penetrating and systemic active ingredients. In all plots, an unsprayed part of at least 200 m^2 was used to follow the epidemic of downy mildew. Results were obtained by regular scoring of downy and powdery mildews in the control plots, counting four replicates of 100 leaves and 50 bunches, compared with the sprayed part after Vitimeteo. The diseased leaf surface was visually estimated (0, 1=0-2.5%, 2=2.5-10%, 3=10-25%, 4=25-50%, 5=>50%) and disease frequency and severity was calculated. Experiments were specifically designed to evaluate the efficacy of spraying schedules used by the growers (different active ingredients) conventionally dosed, compared to the adapted dosage after Siegfried et al. (2007). The fungicides used were contact active ingredients (folpet, sulphur, copper), penetrating a.i. (strobilurines, cymoxanil, triazols, amide carbamates) or systemic a.i. (Al-fosetyl, phenylamides) applied at the recommended concentration, adapted to the leaf area (Siegfried et al., 2007) or to the growth stage (Viret and Siegfried, 2009).

Downy mildew laboratory under natural conditions

An observation laboratory under field conditions has been build up for the validation of Vitimeteo. Control sensitive cv. Pinot noir and Gamay vines are planted with a stock of downy mildew infected leaves underneath, placed every year in autumn. To follow oospores maturation, leaf pieces of approx. 5 mm^2 are selected under the binocular (to ensure the presence of oospores) and placed in Falcon tubes of 50 ml deep in the soil. In spring, at regular intervals, the leaf pieces are transfered in Petri dishes at 100% rH and the emergence of primary sporangia counted every day under the binocular. Oospores are considered mature, when germination occurs within 24 h. From that date on, trap-plants (cuttings with 6-7 unfolded leaves cv. Chasselas grown during winter in greenhouse) are placed always before rainfalls over a stock of infected leaves and removed in the greenhouse after the rain, to check for oil spots (100% rH, darkness, 20°C).

Results and discussion

Effective epidemics and Vitimeteo calculation

Validation of the model Vitimeteo by comparing data from field observations and calculated infections shows a good correspondence (tabl. 1). Under the climatic conditions of Changins, oospores reach maturity between April 30 and May 11, when vine have two to four unfolded leaves (tabl. 1). Maturity of the oospores is not a limiting factor for the beginning of the epidemics under the given Swiss climatic conditions. Quantitatively, the maximum number of sporulating oospores after that date occurs in the same period of time and no correlation could be found between the amount of germinated oospores and the severity of the infection during summer. The total amount of rain from January to May had no influence on the germination rate of the oospores or on severity of the epidemics. In Vitimeteo, the date of maturation of the oospores can be indicated manually or is calculated using the daily temperature sum of 160°C (>8°C) from the first of January. Table 1 shows, that this date can be later as the effective observed dates of germination. To be more in accordance with the effective germination, the limit value for the temperature sum >8°C was adjusted in Vitimeteo at 140°C for the French part of Switzerland. Calculation of the primary infection can only be confirmed by the appearance of oil spots on trap-plants or on vine. The data obtained during the last 5 years with trap-plants indicate that the predicted infections are generally before the occurrence of downy mildew in the vineyard beneath. This can be explained by the vulnerability of the cuttings used as trap-plants, and the physical vicinity of the healthy leaves to the infected leaf stock. The calculated date of the first primary infections by Vitimeteo under variable climatic conditions is generally earlier as the date related to the observed oil spots at the end of the incubation time. This may give a certain safety for the growers at the beginning of the season. For the rest of the growing season, the number of infections indicated by Vitimeteo is in accordance with the disease development in the field reflected by the severity.

On-Farm experiments with Agrometeo and Vitimeteo

Generally, the use of Vitimeteo for the management of diseases and pests is evaluated positively by the extension services and by the vine-growers. Under the Swiss conditions with locally high downy mildew pressure, Vitimeteo is a precious tool for a more precise control of the disease. Growers using it are spraying more in accordance with the epidemic and in dry years they can objectively delay the first spray and decide to enlarge spray intervals, reducing the number of sprays. Globally considered, the reduction of the number of sprays can be of two to three, when disease pressure is weak (Tabl. 2). The total number of infections calculated by the model Vitimeteo (tabl. 2) is proportional to the disease severity (tabl. 1) and related to the number of spray application by the grower (tabl. 2).

Vitimeteo is every year more used by the growers, as shown by the statistics of requests on the internet site. Between 2006 and 2009, the mean yearly increase of requests reaches 15%, with over 100'000 in 2009. One of the most important points is the quality of measurements on the field and the reliability of the data which have to be checked before being integrated in any models. In the Agrometeo database, this check is automatically performed when the values are communicated by the weather stations and the stations are regularly surveyed in the field by specialists.

Leaf area-adapted dosage of fungicides

The disease pressure of downy mildew at Perroy, a place located on the lake of Geneva in a relative humid area is presented in table 3. Every year, the unsprayed control is nearly destroyed by the pathogen and no yield can be harvested. The leaf area adaped spraying follows the growth curve of the vines. This approach allows a reduction of the amount of fungicides against both, downy and powdery mildews of 15 to 26% compared with the linear growth stage adapted dosage (tabl. 3). Yearly variations depend on the climatic conditions and on the spraying schedule, especially before and during bloom. The years with very high downy mildew pressure (2006, 07, 08), both dosages present diseased leaves and bunches, but no significant differences could be found. In these years, no economical losses could be found, except in the unsprayed control. The adaptation of the dosage to the leaf surface is easy to use in Agrometeo, but can only be performed in trellised vineyards with properly calibrated spraying equipments.

Table 1. Biological and epidemiological characteristics of downy mildew on cv. Chasselas, Changins (VD), 2005-2008, under natural conditions. Oospores maturation, trap plants, number of infections, growth stage of the vine, and rainfalls. Downy mildew epidemic: 0, absence; (+), few oil spots; +, weak presence; ++, strong epidemic; +++, very strong epidemic, locally with economical losses.

	2005	**2006**	**2007**	**2008**	**2009**
Date of oospores maturation (germination within 24h) Growth stage BBCH	02 May 12	11 May 51	30 April 51-52	5 May 12	4 May 51
Maximal number of oospores sporulating after the date of oospore maturation Growth stage BBCH	06 May 13	11 May 51	30 April 51-52	5 May 12	11 May 53
Mean number of germinated oospores per count	70.7	28.1	27.8	121.9	149.1
Sum of rain (January to May)	339 mm	478 mm	348 mm	369 mm	190 mm
Temperature sum (>8° C) = 160° Growth stage BBCH	8 May 13	13 May 51	25 April 51	14 May 52	8 May 51
Date of first primary infection after Vitimeteo	14 May	18 May	30 April	16 May	27 May
Date of first oil spots in vineyard	06 June	22 May	29 May	26 May	25 May
Downy mildew on trap-plants	never	12 May	12 June	26 May	26 May
Beginning of exponential development of epidemic	en July	end May	mid June	end May	end June
Total number of secondary infections before bloom	1 (+)	4 +	15 +	17 ++	1 (0)
Total number of secondary infections during bloom	2 (0)	5 (+)	4 (+)	3 (+)	9 (0)
Total number of secondary infections after bloom	17 (+)	34 +	37 +++	24 ++	20 +
Sum of rain (May to August)	256 mm	319 mm	536 mm	338 mm	215 mm

Table 2. Downy mildew on cv. Chasselas, Perroy (VD). Rainfall sum (mm), date of the first primary infection calculated by Vitimeteo, appearance of the first oil spots, sum of monthly infections, total number of sprays to control downy and powdery mildew from May to August 2005-2008.

	2005	**2006**	**2007**	**2008**	**2009**
Date of primary infection indicated by Vitimeteo	16 May	16 May	27 April	16 May	15 May
First oil spots	9 June	29 May	6 June	29 May	5 June
First spray application	24 May	19 May	1 May	23 May	5 May
Beginning of bloom	13 June	14 June	29 May	14 June	9 June
Number of sprays	7	8	9	10	8
Rain (mm)					
May	59	147	175	87	29
June	67	45	173	57	109
July	49	59	187	91	93
August	69	156	155	103	87

Sum	244	407	690	338	318
	Number of downy mildew infections indicated by Vitimeteo				
May	1	2	22	6	3
June	5	7	19	13	12
July	5	7	16	21	12
August	9	17	18	17	10
Sum	**20**	**31**	**75**	**57**	**37**

Table 3. Leaf area adaped dosage of fungicides, Perroy (VD) cv. Chasselas. Downy mildew on leaves and bunches (% frequency, in parentheses % intensity) observed at the end of August (average of 4x 100 leaves and 4x 50 bunches per plot). The standard dosage, correspond to the linear adaptation of spray broth volume depending on the growth stage of the vine, currently used in Switzerland. The adaptation rate is the difference between the leaf area adapted dosage and the standard dosage expressed in %.

	Unsprayed control		**Leaf area adapted dosage after Siegfried et al. (2007)**		**Standard dosage**			
	Leaves	Bunches	Leaves	Bunches	Leaves	Bunches	Number sprays	Adaptation rate
2005	97 (40.9)	7.3 (0.5)	8 (0.7)	0 (0)	7.3 (0.5)	0 (0)	7	15.6
2006	99 (61.5)	100 (32.7)	42 (9.6)	2.6 (0.1)	31.9 (7.1)	0.6 (0.01)	8	19.7
2007	100 (94.1)	100 (44.6)	23.8 (10.1)	4.2 (0.3)	18 (6.7)	3.3 (0.1)	9	22
2008	97 (48)	100 (44.7)	51.3 (10.2)	27.3 (7.6)	49.7 (9.9)	16.5 (4)	10	25.7
2009	88 (38.4)	52.7 (6)	7.3 (1.3)	0.7 (0.1)	1.7 (0.5)	1.3 (0.1)	8	26.1

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