Relations between spring rainfall and infection of sunflower by *Plasmopara halstedii* (downy mildew)

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ABSTRACT

The incidence of spring rainfall on the severity of primary downy mildew attack of sunflower was studied in field trials with staggered sowing dates. Infection potential of soil depended partly on rainfall probably because, in damp conditions, oospores germinate and must infect sunflower rapidly. In contrast, under dry conditions, they remain dormant and thus maintain their infection potential. Disease risk appears greatest if there is heavy rainfall when sunflower seedlings are at their most susceptible stage, between germination and emergence. Heavy rainfall before sowing had no effect on percentage of diseased plants and heavy rainfall after seedling emergence did not increase primary downy mildew attack.

Key words: disease risk epidemiology – downy mildew – *Helianthus annuus* – infection potential – soil test.

RESUME

La mise en place de semis décalés sur deux années présentant des conditions climatiques différentes a permis de préciser l'influence des précipitations printanières sur l'expression de la forme la plus dommageable du mildiou qui est l'infection primaire tellurique. D'une part, le potentiel infectieux du sol évolue au grès des pluviométries. Les pluies continues épuisent le stock d'inoculum alors qu'une période sèche fait grimper le pouvoir infectieux de sol au niveau de l'horizon correspondant au lit de semence. D'autre part, le risque mildiou est étroitement lié à la présence de pluies abondantes au moment où la plantule présente une forte sensibilité aux infections telluriques. C'est-à-dire entre le début de la germination et l'émergence des cotylédons. Les fortes pluies qui interviennent avant la germination n'ont que peu d'impact sur le taux de plantes malades. Les fortes pluies qui arrivent après la levée n'augmentent pas le nombre d'infections telluriques. L'utilisation de ces informations épidémiologiques devrait être intégrées à la construction d'un modèle d'analyse de risques.

Mots clés: analyse de risque –épidémiologie – *Helianthus annuus* – mildiou – potentiel infectieux – test sur terre.

INTRODUCTION

Plasmopara halstedii is a soil-borne parasite, which remains in the soil in the form of oospores. These spores are produced by sexual reproduction and may remain dormant but viable for up to 10 years. Under favourable conditions, oospores germinate to give zoosporangia which, in the presence of free water, liberate mobile zoospores. These cause primary infections of sunflower radicles, leading to systemic attacks that cause most loss to the crop. Rainfall is a major climatic factor determining disease risk. Delos et al. (2000) considered that rainfall just before or after sowing was the most favourable for downy mildew infections of sunflower. To determine in more detail the effect of rainfall on percentage attack, in 2006 and 2007, sunflowers were sown at weekly intervals and detailed records were made of rainfall, soil temperature and numbers of plants showing systemic downy mildew symptoms. The infection potential of the soil in the fields concerned was measured by a growth chamber test developed by Tourvieille de Labrouhe and Walser (2005). Correlations between the different factors were determined in order to define those that should be included in models predicting disease risk.

MATERIALS AND METHODS

Sunflower genotypes

The inbred sunflower line GB (INRA, Clermont-Ferrand) was used both for soil tests in the laboratory and to measure downy mildew attack in the field. This line has no known downy mildew resistance gene.

Field trials

Trials were carried out in fields near Clermont-Ferrand (Auvergne) naturally infected with race 710 of *P.halstedii.* Each year, 10 zones were defined in the field and, in each, one 3m row was sown with the inbred line GB every week from 21st of March to 6th of May in 2006 (8 sowing dates) and from 13th of March to 15th of May in 2007 (10 sowing dates).

Observations of weather conditions

Rainfall was obtained from Météo-France at Clermont-Ferrand airport (at 1km). Soil temperature was measured with a recorder (xvacq de TMI Orion) measuring the temperature at a depth of 3cm every hour.

Field observations

The trials were observed each week from seedling emergence to 2 pairs of leaves. The numbers of plants showing systemic downy mildew symptoms resulting from primary infections through the roots were counted.

Soil test

The day before soil sampling, sunflower seeds were germinated at 100% RH after soaking in water for 2 hours. Soil was sampled at a depth corresponding to that at which sunflower seeds are normally sown. The samples were placed in trays and the germinating seed sown at a depth of 1cm. After 48h at 18°C, the trays were immersed in water for 8h. They were then incubated for 12 days at 18°C and 12000 lux light 16h/24. To determine presence of downy mildew, the trays were covered with a plastic bag to obtain 100%RH for 48h and then observations were made of sporulation on cotyledons and true leaves (Tourvieille de Labrouhe and Walser, 2005).

RESULTS

Weather conditions

Rainfall, mean daily temperatures and sowing dates are presented in Fig. 1 and 2.

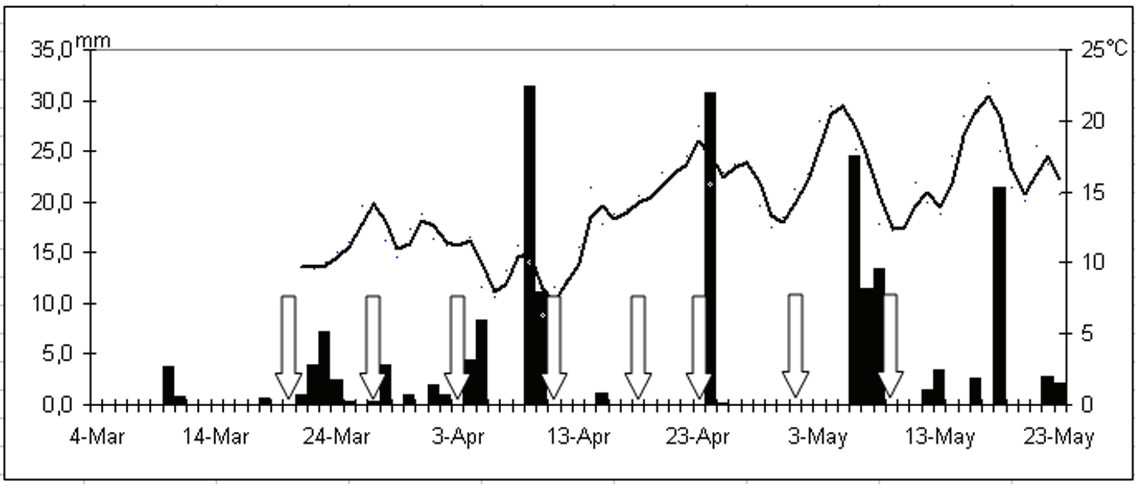

Fig. 1. Soil temperature and rainfall in 2006. Arrows indicate sowing and soil sampling dates

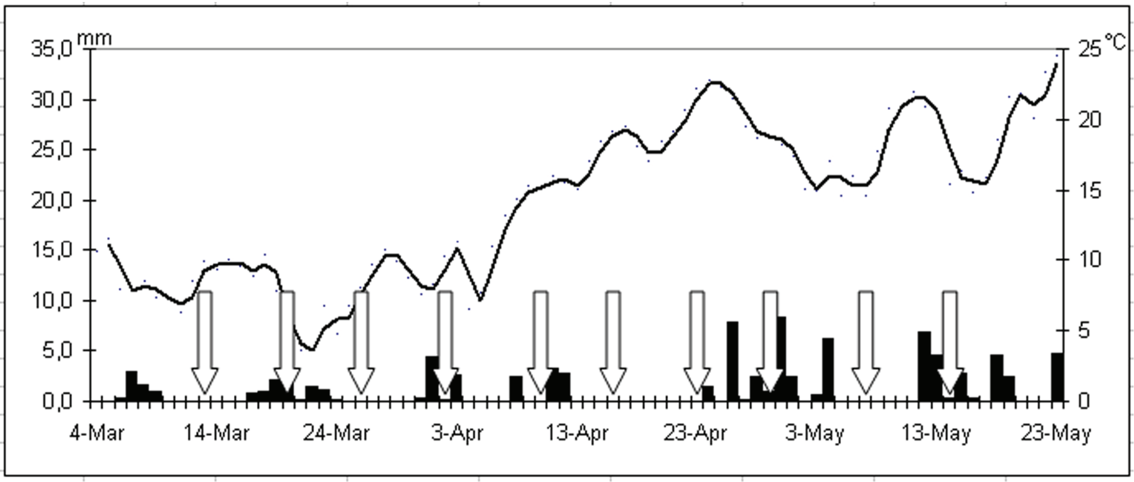

Fig. 2. Soil temperature and rainfall in 2007. Arrows indicate sowing and soil sampling dates

Weather conditions were very different in 2006 and 2007. In 2006, the period studied was cool (mean temperature 15°C) with some heavy rain (178mm, including 42mm 9-10/4, 31mm 24/4, 49mm 6-8/5 et 21mm 18/5). 2007 was much warmer (mean temperature 18°C) and drier (less than 100mm, with 12mm 29/4-1/5 and 14mm 12-15/5).

Variation in downy mildew attack according to sowing date
Table 1 presents percentage primary attacks in 2006 and 2007.

Table 1. Mean percentage downy mildew attack for each sowing date (10 plots for each date)

2006		2007	
Sowing date	% attack	Sowing date	% attack
		March 13rd	0.0
March 20th	16.3	March 20th	1.1
March 27th	44.0	March 26th	0.4
April 3rd	25.1	April 2nd	0.0
April 11th	32.5	April 10th	2.2
April 18th	23.3	April 16th	13.2
April 23rd	34.9	April 23rd	12.9
May 1st	16.0	April 30th	2.0
May 9th	11.6	May 7th	0.2
		May 14th	0.8

In 2007, only 2 dates (16/4 and 23/4) showed more than 10% attack (with a maximum of 39% for one plot), in contrast with 2006 when mean attack was 11 to 44%, with a plot maximum of 83%. Both years showed a considerable variation between sowing dates.

Soil infection potential according to sampling date
Fig. 3 and 4 show the variations in infection potential measured by the laboratory soil test. Potential infection varied considerably according to the zones in the field where soil was sampled but also according to sampling date. The lowest levels were found in March, and in April the greatest potentials were observed for 2 dates: 3/4 and 23/4 in 2006 and 2/4 and 23/4 in 2007.

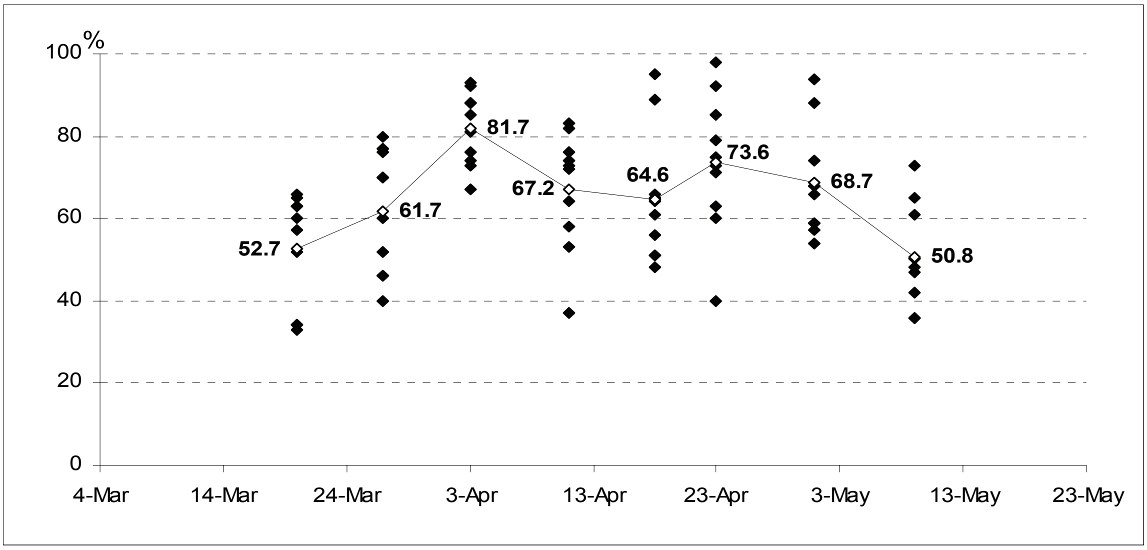

Fig. 3. Variation in percentage of seedlings showing downy mildew symptoms according to date of soil test (10 samples per date) for 2006

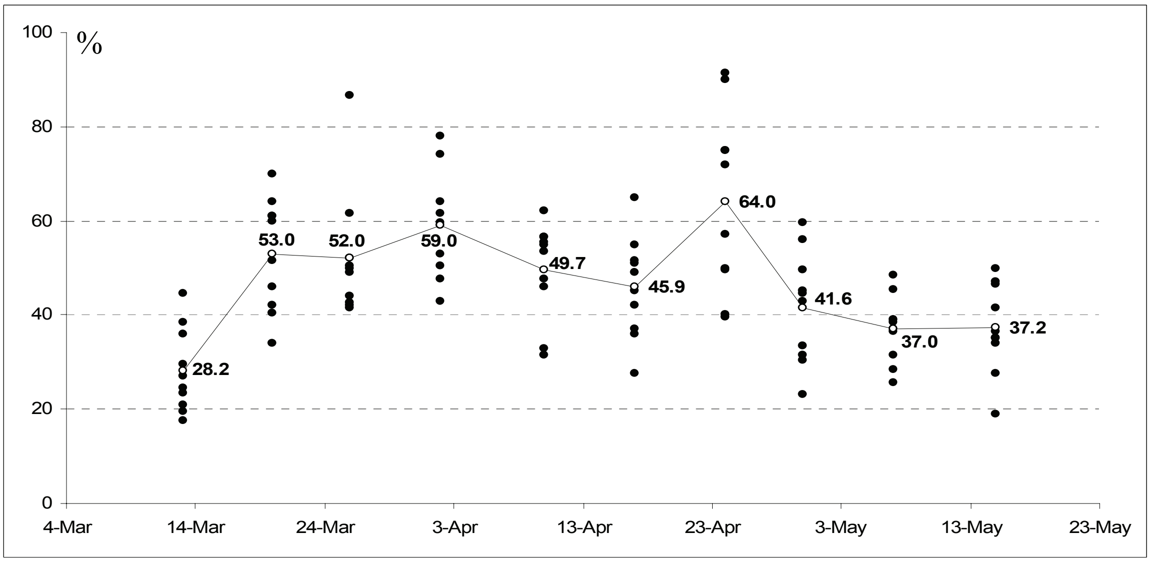

Fig. 4. Variation in percentage of seedlings showing downy mildew symptoms according to date of soil test (10 samples per date) for 2007.

Relations between rainfall and soil infection potential

There was a negative relation between rainfall and soil infection potential. This was confirmed by comparison between total rainfall 10 days before sampling and the percentage of diseased plants in soil tests (Table 2). The negative correlation coefficient was highly significant in 2007, an unfavourable year for downy mildew, especially if only April is considered.

Table 2. Correlation coefficients (Pearson) between rainfall and soil infection potential

	2006		2007	
	March-May	April	March-May	April
Number of replicates (10 plots by date of sowing)	80	40	100	50
Correlation coefficient				
- Infection potential / rainfall 10 days before sampling	r= - 0.166	r= -0.337*	r= - 0.416**	r= -0,513**
- Rate of attack / rainfall between ”sowing + 166 h. with > 7°C” and ”sowing + 360 h. with > 7°C”	r= 0.383**	r= 0.403**	r= 0.513**	r= 0.522**

* significant at p = 0.05, ** significant at p = 0.01

Relation between rainfall and downy mildew attack in the field

Correlations were calculated between percentage of primary attack and rainfall in the pre-emergence period taking into account soil temperature, which is important for rapid emergence The closest correlation was with rainfall in the period from sowing +166h at above 7°C and sowing + 360h at 7°C (Table 2). For both years, the correlation coefficients were highly significant.

DISCUSSION

The effect of rainfall on the level of downy mildew attack was analysed for 2 very contrasting years. In neither year was there any water deficit, but whereas 2006 had some days of heavy rain interspersed with dry periods, in 2007 there were no heavy rains but regular damp periods. These differences are useful to make general conclusions.

The fields used in 2006 and 2007 had shown comparable levels of downy mildew attack in preceding years, suggesting that they should have similar inoculum potentials (Tourvieille de Labrouhe et al., 2008). The present results indicate quite clearly that the risk of downy mildew attack depends closely on pattern and intensity of rainfall. Délos et al. (2000) reported that rainfall ought to be sufficient to give the free water in the soil necessary for zoospore movement. The low levels of attack in March 2006 and 2007 may be explained not only by lack of rainfall but also low infection potentials, as measured by the soil test. The limiting factor could be the level of inoculum maturation, which depends on soil temperature.

The low levels of attack on the last sowing dates, in May, when there was considerable rainfall, especially in 2006, also suggest that the limiting factor was also a low level of inoculum. This was confirmed by soil tests. It appears likely that the inoculum present around seeds had been used up by the end of April. Infection potential varied between weeks, and soil samples taken after a dry period (when zoosporangia may not have been produced) always showed an increase in infection potential. This observation was confirmed by the negative correlation between rainfall in the 10 days preceding soil sampling and the infection potential of this sample. As suggested by Délos et al. (2000), rainfall may be necessary to obtain free water in the soil for zoospore movement, but it could also be suggested that rainfall leads to production of inoculum which can only cause infection over quite a short period (Goossen and Sackston, 1968), so that none remains in later weeks. Thus, in addition to a variable level of infection potential over the whole period, with a maximum in mid-April, (Tourvieille de Labrouhe et al., 2008), daily variation may occur according to soil humidity. The trials have not been made under very dry conditions so no data is available as to the length of time necessary for oospores to produce zoosporangia when conditions become favourable for the parasite. It would be useful to carry out laboratory tests on soil samples subjected to variable periods of drying.

Délos et al. (2000) reported that attack levels were closely correlated with rainfall from 5 days before sowing to 5 days after sowing. The present results did not show this correlation. Taking into account minimum growth temperature (6°C; Merrien, 1992) and sunflower germination optimum (8°C; Anonymous, 2003), a close relation appeared between rainfall at sowing date + 166h above 7°C (beginning of radicle growth) and sowing date + 360h at above 7°C (emergence). This is generally equivalent to 5 to 15 days after sowing, later than that suggested by the earlier results.

These epidemiological results should help in the construction of a model concerning disease risk. The probability of the appearance of plants showing downy mildew symptoms depends on many factors, of which the following appear to be the most important:

- The level of infestation of the field , which will depend on the number of diseased plants in the preceding sunflower crop (Tourvieille de Labrouhe et al., 2008).
- The use of resistant sunflower varieties and the development of downy mildew races virulent on these varieties (Vear et al., 2007).
- Seed dressing with fungicide and resistance of downy mildew isolates to this fungicide (Gulya, 2000).
- crop management practices which could affect disease development (Covarelli et Tosi, 2007; Escande et al., 2007).
- Rainfall between germination and emergence.
- Soil infection potential on level of seed bed.

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