Chemical control of pepper mildew *Phytophthora capsici* (Leon), on early peppers in Tunisia

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Summary

Peper mildew, caused by Phytophthora capsici, *is a serious problem in the intensive early cultures of the Tunisian Nebhana region.*

In experiments done in very severe conditions of contamination, the best control was obtained by a weekly soil drench (100 ml per lant) with the commercial metalaxyl + maneb mixture (40 g + 192 g.hl^{-1}). The protection continued up to 5 weeks after the end of the treatment. The action of foliar sprayings was slower and not remanant.

The effectiveness of captafol and phosethyl-aluminium soil drenches (0.2 g and 0.4 g per plant) was poor. An improvement of the control was obtained by diluting a dose of 0.4 g captafol per plant in a greater quantity of water (500 ml).

Phytotoxic symptoms appeared on the leaves of the pepper plants after all metalaxyl + maneb treatments, but not after the other fungicide applications.

Résumé

Phytophthora capsici, *agent causal du mildiou du piment, gagne en importance dans les cultures de primeurs de la région de Nebhana en Tunisie.*

Dans nos essais exécutés dans des conditions sévères de contamination, la meilleure lutte a été obtenue par l'arrosage hebdomadaire (100 ml par plante) du mélange commercial de métalaxyl + manèbe (40 g + 192 g.hl^{-1}). La protection continuait même jusqu'à 5 semaines après le dernier traitement. L'action des applications foliaires était plus lente et pas rémanante.

L'efficacité de captafol et de phoséthyl-aluminium, appliqués en arrosage (0.2 g et 0.4 g par plante), était faible. Une certaine amélioration de lutte était obtenue en diluant une dose de 0.4 g de captafol par plante dans une quantité d'eau plus importante (500 ml).

Des symptômes de phytotoxicité sont apparus sur les feuilles du piment après toutes les applications de métalaxyl + manèbe; les traitements aux autres fongicides étaient sans danger pour la culture.

Pepper mildew, caused by *Phytophthora capsici* Leon, is an important soil-born disease in pepper cultures in the mediterranean area. Recent work on its chemical control has been reported from Bulgaria (4,5), Turkey (2, 11) and Yougoslavia (1). Also in more temperate climates, such as the Netherlands, pepper crown rot caused by this pathogen became a problem under greenhouse conditions (10).

In Tunisia pepper mildew is also present, especially in the intensive early cultures of the Nebhana region. One of the major reasons for the deterioration of the phytosanitary conditions of the cultures is the predominant place the pepper crops occupy in the region: in 1980 and 1981, respectively 61,7 % and 69,1 % of the area was planted with hot and, to a lesser extent, bell peppers. The traditional method of furrow irrigation also favours the spread of the disease by its zoospores.

Successful work on the resistance of peppers to *P. capsici* is being done at Montfavet, France by Pochard and his collaborators. However, as resistance to *P. capsici* is not yet present in commercial hot pepper cultivars, control with specific fungicides represents the only way for limiting yield reduction.

The present paper reports on experiments made to control pepper mildew with two promising systemic fungicides, metalaxyl (in combination with maneb) and phosethyl-aluminium.

Materials and methods

The experiments (cross classification, fixed model with 3 replicates) were set up in plastic greenhouses in the governorate of Monastir in March-April 1982. Some pepper plants, distributed quite homogenously over the whole experimental area, showed the typical symptoms of pepper mildew.

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In the first two experiments performed at Teboulba (Teb) and Monastir (Mon 1) the mixture metalaxyl + maneb was applied at concentrations of 20 + 96, 40 + 192 or 80 + 384 g/hal while phosethylaluminium was used at 20, 40 or 80 g/hl. Plots were planted with 10 or 20 pepper plants cv. Beldi on one or both sides of an irrigation trench. Fungicides were applied weekly (100 ml/plant) with a knapsack sprayer on the leaves or by soil drenches around the stems. Treatments were stopped respectively in Teboulba and Monastir after 6 and 12 weeks.

In the third experiment (Mon 2) phosethyl-aluminium was compared with captafol. Both fungicides were applied for a period of 4 months at 0, 0.2 or 0.4 g active ingredient per plant. Each dose was diluted in either 125, 250 or 500 ml water and administered weekly as a soil drench during 4 months.

In the forth experiment (Mon 3), the same doses of phosethyl-aluminium and captafol were applied weekly in aliquots of 100 ml. Treatments were stopped 1, 2, 3 or 4 months after the first application.

Plots in the last 2 experiments contained about 20 plants (cv. Beldi) situated on both sides of the irrigation trench.

Disease observations were done weekly in all experiments. The harvest was done bi-weekly, except in Teboulba where the harvest started before the fungicidal interventions.

Results

Evolution of the disease on unprotected plants

The spread of pepper mildew on untreated plants was near to linear at its beginning, but increased markedly after 15 to 18 weeks (Fig. 1). By the end of June, from 35 percent to more than 40 percent of the control plants were attacked at Monastir, while at Teboulba, 31 percent of the control plants were wilted or dead 11 weeks after the breaking out of the disease. In the Mon 1 and Teb experiments, wilt disappeared sometimes during cold days with overcast skies but these plants became later irreversibly wilted.

Influence of the fungicide and its dosage on disease expression

In the Mon 1 and Teb experiments, disease was best controlled with the metalaxyl + maneb mixture. Differences in efficiency between the used doses of the fungicides were not important during the complete treatment period. Plants who received the lowest dosage (20 + 96 g/hl) wilted after discontinuing fungicide applications (Table 1 and Fig. 2). In all four experiments, protection was very variable for phosethyl-aluminium treatments. Increasing the dose did not always result in an improvement of the efficacy (Table 1 and 2). Effectiveness of captafol

TABLEAU 1:

Influence of different modes of application and doses of metalaxyl + maneb and phosethyl-aluminium on their effectiveness in the control of *Phytophthora capsici*.

Fungicide	Dose (g/hl)	Mode of application	EFFICACY INDEX (*) Monastir 1 (weeks after the first treatment) 4	8	12	16	17	Teboulba 1	3	5	8	11
metalaxyl + maneb	20 + 96	S	70.46	44.05	55.52	37.03	46.04	-66.07	16.52	9.05	-87.70	-31.79
		D	70.48	81.55	70.00	29.31	39.42	44.40	62.94	39.38	89.58	78.05
	40 + 192	S	100.00	100.00	85.00	35.00	37.00	100.00	44.40	100.00	-25.23	-05.45
		D	70.02	81.26	85.00	89.50	91.00	72.24	86.10	54.53	84.35	80.23
	80 + 384	S	-21.78	100.00	100.00	78.80	45.56	-39.17	16.52	8.89	-9.58	14.39
		D	59.80	62.52	70.00	75.33	78.86	25.89	90.74	84.86	89.58	82.45
phosethyl-aluminium	20	S	40.04	-199.85	-50.00	68.00	-61.96	-66.96	16.52	100.00	-87.88	-58.16
		D	10.08	24.98	24.96	36.97	45.98	-11.37	16.52	8.91	-56.60	-58.16
	40	S	-319.66	-87.41	-170.98	-194.00	-151.94	-122.57	44.32	54.53	37.43	47.29
		D	20.07	31.28	45.99	61.49	66.92	44.32	-13.82	-13.82	6.06	20.92
	80	S	40.05	12.56	-19.88	9.01	22.02	100.00	100.00	100.00	-56.60	-45.00
		D	-157.27	-181.39	-157.38	-80.17	-73.68	-11.37	100.00	-127.64	-25.23	34.09

(*) efficacy index according to Henderson-Tilton (7), S : foliar spray (100 ml/plant), D soil drench (100 ml/plant).

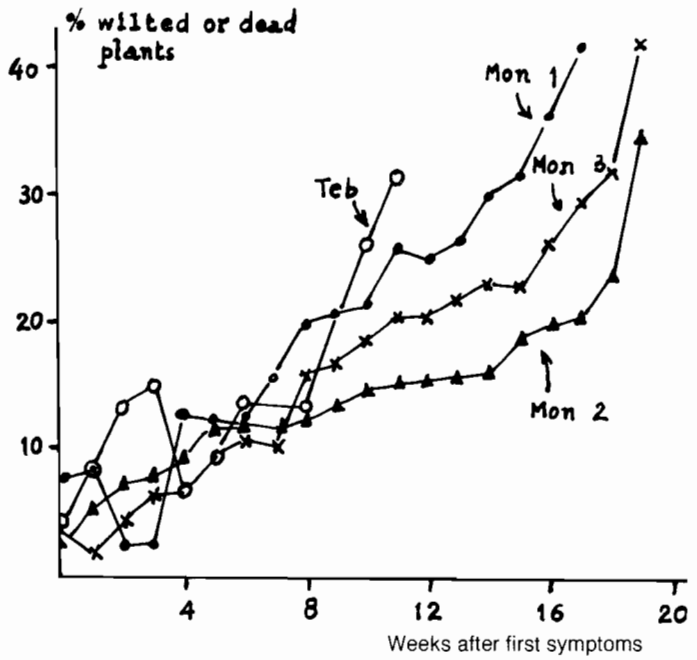

Figure 1 : Evolution of wilting caused by *P. capsici* on untreated pepper plants at 4 experimental sites.

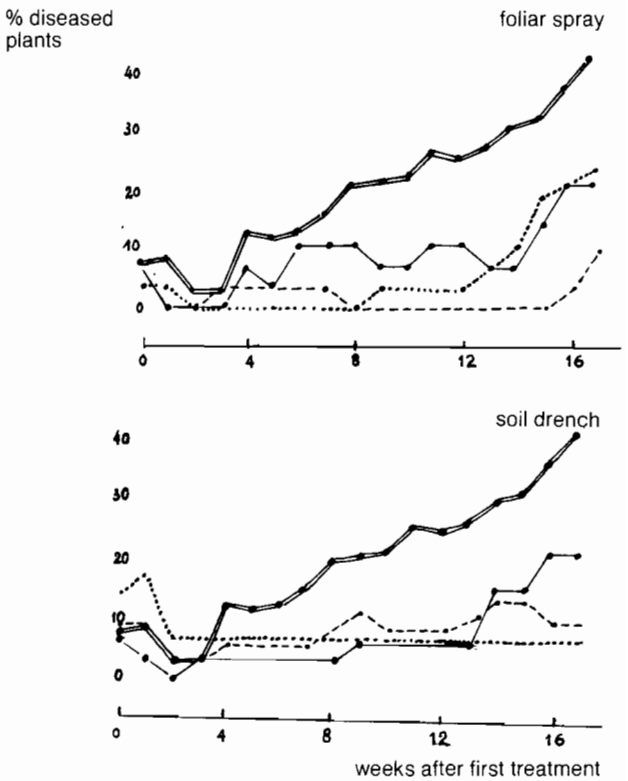

Figure 2 : Evolution of the spread of wilting caused by *P. capsici* after different treatments of metalaxyl + maneb.

- untreated control
- 20 g metalaxyl + 96 g maneb/hl
- 40 g metalaxyl + 192 g maneb/hl
- 20 g metalaxyl + 384 g maneb/hl

TABLE 2

Influence of the dilution of phosethyl aluminium and captafol on their effectiveness against *Phytophthora capsici*.

Fungicide	Dose (g/plant/ treatment	Water quantity per plant	EFFICACY INDEX (*) (months after first treatment) 1	2	3	4
phosethyl aluminium	0.2	125	—5.89	14.95	25.07	22.15
		250	9.20	—69.96	—83.12	—81.57
		500	39.65	—27.32	—82.82	42.42
	0.4	125	39.29	—6.56	—0.13	—121.11
		250	39.47	25.62	—24.90	—23.25
		500	—21.25	—6.44	16.61	—55.70
captafol	0.2	125	39.47	—69.96	16.83	—16.69
		250	33.38	—87.21	—83.33	—142.74
		500	69.73	14.95	16.72	—16.78
	0.4	125	9.20	—91.36	—83.22	—81.65
		250	39.29	—91.36	—33.65	—30.14
		500	51.61	61.75	46.70	58.48

(*) Efficacy index according to Henderson and Tilton (7).

treatments was situated between the two former fungicides and depended strongly on the volume of the applied aliquots (Table 2).

Influence of the site of fungicide application on disease expression

The commercial metalaxyl + maneb mixture, applied as soil drenches, gave at Teb nearly always the highest effectiveness (Table 1) and even after the treatments were discontinued, plants remained healthy. Application as foliar spray had a variable effect and was devoid of remanence. In the Mon 1 experiment, the control obtained was satisfactory for both types of application. After discontinuing the treatments, only plants treated by soil drenches with the two highest doses continued to be protected.

At Mon 1, soil drenches with phosethyl-aluminium gave a better, although not satisfactory, protection than foliar sprayings with the same fungicide. Only applications of 800 ppm on the foliage were more effective than soil treatments. At Teboulba, where the best results were obtained with sprayings, the control was complete, even with applications of 800 ppm, but failed after the treatments were discontinued.

Influence of fungicide dilution on its effectiveness

The influence of the water quantity used for soil drenches was variable with the fungicide and its dose. Phosethyl-aluminium drench applications gave better results than those with captafol. Protection was very poor when the lowest dose (0.2 g) was diluted in the smallest quantity of water.

At the beginning captafol treatments gave a rather good protection with the smallest dose (0.2 g/plant) diluted in 500 ml water, but afterwards doubling of the original dose in 500 ml water was necessary (Table 2).

Influence of duration of the treatments

In order to estimate the after effects of the treatments, we calculated a disease multiplication factor. This factor is determined at any time after the last treatment as the ratio between the percentage of wilted plants at that moment and the percentage of diseased plants at the time when treatments were discontinued. Any after effect of phosethyl-aluminium was non existant. Captafol treatments kept the pepperplants moderately healthy after they were discontinued (Table 3). For short duration treatments (1 and 2 months) with this fungicide the after effects were greater with the highest dose. The disease multiplication factor remained low after long duration treatments (3 and 4 months).

TABLE 3

Influence of the duration of a captafol treatment on the evolution of wilting caused by *Phytophthora capsici*.

Duration of treatment (months)	Dose (g/plant/ treatment)	Disease multiplication factor (*) (months after first treatment) 1	2	3	4	5
1	0.2	1.00	3.50	4.50	5.50	9.00
	0.4	1.00	2.70	3.30	2.50	2.80
2	0.2	—	1.00	1.75	2.00	3.00
	0.4	—	1.00	1.00	1.66	2.60
3	0.2	—	—	1.00	0.90	1.60
	0.4	—	—	1.00	0.90	1.00
4	0.2	—	—	—	1.00	1.20
	0.4	—	—	—	1.00	1.20

(*) Ratio of percentage of wilted plants on a moment and that at the time the treatment were discontinued.

Influence of fungicide treatments on pepperplants and on their production

Phytotoxic symptoms appeared on the leaves after the third metalaxyl + maneb treatment. Four months after the first treatments, the following reactions were noted at Monastir 1 (Table 4). Spraying with 20 + 96 g per hl induced a yellowing of the leaf margins. Phytotoxic reactions became more apparent as dosages increased. For a given dose, phytotoxicity was more evident after soil drenches than after foliar sprayings. Size reduction and deformation of the leaves to a spoon form occurred only for the highest doses. The phytotoxic reactions were irreversible.

Since it was not possible to control harvest after 21 st May, a significant influence of the fungicides on the yield couldn't be observed in the Mon 1 experiment. Nevertheless, differences in the number of fruits per plant were nearly statisticaly significant and in favour of the metalaxyl + maneb treatment. In the other experiments done at Monastir, no significant differences were found at all.

TABLE 4

Phytotoxic reactions of pepperplants after repeated treatments with metalaxyl + maneb during a 4 months period (Monastir, 3.7.1982).

Dose	Made of treatment	Yellowing: interior	Yellowing: margins	Yellowing: intensity	Necrosis	Size reduction	Deformation
20+ 96	S	0 (a)	3 (a)	2 (3) (b)	0 (a)	0 (a)	0 (a)
	D	1	3	2.3.5	1	0	0
40+192	S	0	3	(3) 4	1	0	0
	D	2	3	(3) 4	2	0	1
80+384	S	3	3	5.7.8	3	2	1
	D	3	3	7 (8)	3	3	3

S: spraying
D: drench
(a) number of replicates with symptoms (max: 3)
(b) semilogarithmic scale of the European Weed Research Council (1 =without yellowing, 9=100 % yellowing).

Discussion

A survey of the Nebhana area during the year 1982 showed that the appearence of pepper mildew was rather variable, generally situated within the period February to June (Moens and Ben Aïcha, unpublished). Wilting in early pepper crops occured principally during the hot summer months (June and July), this confirming data obtained earlier (8).

The four experiments were done under very severe conditions of infection. As the crops were furrow irrigated, and as control and less protected plots were dispersed over the whole experimental area, continuous cross contamination between different plots was possible.

Farih, Tsao and Menge (6) demonstrated that metalaxyl can control *Phytophtora* diseases by effecting the pathogens at any or all stages of their life cycle. Comparing the in vitro toxicity of captafol and metalaxyl toward *P. capsici*, Papavizas and Bowers (9) showed that the former was more toxic than metalaxyl to those phases in the life cycle that are normally completed in a relatively short period of time. These stages (zoospore release from sporangia, zoospore motility and direct germination of sporangia and zoospores) are essential for successful foliar infections. Metalaxyl was more inhibitory than captafol to oospore and sporangial production, two major ways of dessimination of the fungus.

Our experiments confirm those observations; indeed, the best results in controlling *P. capsici* crown rot were obtained with the metalaxyl + maneb mixture. Application by drenching prevented the spread of disease in both experiments in which it was used and even up to 5 weeks after the treatments were discontinued, pepper plants remained well protected. The action of foliar sprayings was slower and could not assure protection after 5 weekly treatments.

The poor results obtained with captafol and phosethyl-aluminium used as 100 ml aliquot confirm earlier work (8) done under similar conditions of possible cross contamination; both fungicides even increased wilting, showing negative efficacy indexes. The improved control obtained by diluting captafol in a larger quantity of water might be explained by a better wetting of the soil by the fungicide solution, so that deeper roots were protected. Diluting captafol requires an increase of the dose to 0.4 g per plant. To assure a significant protection, soil drench treatments have to be carried out during the whole period of possible contamination; the influence of the dose being only of importance when treatments were discontinued after one month.

The phytotoxic symptoms that appeared on the leaves of pepperplants after application of the metalaxyl + maneb mixture can be attributed do the first component. Not only were yellowings present after sprayings, but also after soil drenches. Chlorosis of the margins of citrus leaves has been described by Davis (3) after treatments with metalaxyl as trunk-paint or soil drench. Egon (personal communication) reported the same symptoms after metalaxyl treatments of grapevines in Italy.

The results obtained in our experiments with metalaxyl + maneb were excellent from some points of view, but might be improved by suppression of cross contamination from adjacent infested plots. The treatments might be reduced in number and spaced in time, thus avoiding phytotoxicity and selection of metalaxyl resistant strains of *P. capsici*. Alternation of such treatments with captafol offers another interesting possibility.

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