Study on the curative and eradicant action of fungicide combinations to control late blight in potato.

B. Heremans[1] and G. Haesaert[2]

[1] Hogeschool Gent – Proefhoeve Bottelare, Department of Biotechnology, Landscape architecture and Agriculture, Diepestraat 1, B-9820 Merelbeke, Belgium
[2] Hogeschool Gent, Department of Biotechnology, Landscape architecture and Agriculture, Voskenslaan 270, 9000 Gent, Belgium
Betty.Heremans@hogent.be

Summary

Commercial fungicide combinations were tested in the field for efficacy on foliar late blight caused by *Phytophthora infestans* in substitution of tin. When the first disease symptoms appeared, the tested fungicide treatments for late blight control were applied 3 times at 3-day intervals. The effect of the fungicide treatments on epidemic development, tuber rot and blight incidence and tuber yields were determined. Last summer late blight development was arrested in June due to high temperatures and lasting drought. August was characterized by rather low temperatures and high rainfall. These weather conditions were very favourable for the development of late blight. The foliar protection against *P. infestans* was comparable for all the tested fungicide combinations. The effect of combinations with dimethomorph + mancozeb (AcrobatC, 2.5 kg/ha) was less suppressive for *P. infestans* than the other fungicides tested. Lowest foliar disease severity was recorded in plots treated with fluazinam (Shirlan, 0.4 l/ha) + cymoxanil + chlorothalonil (Mixanil, 2 l/ha). Furthermore, highest tuber yield was noted in plots treated with fluazinam (Shirlan, 0.4 l/ha) + cymoxanil + chlorothalonil (Mixanil, 2 l/ha). The percentage blighted tubers fluctuated between 5 and 11 %. No fungicide combinations completely arrested epidemic development under the environmental conditions of the trial. However, fluazinam (Shirlan, 0.4 l/ha) + cymoxanil + chlorothalonil (Mixanil, 2 l/ha) controlled *P. infestans* most effectively.

Key words: potato, late blight, *Phytophthora infestans*, fungicide combinations efficacy, curative and eradicant action of fungicides

Introduction

Potato late blight, caused by *P. infestans* , remains one of the most serious constraints to potato production world wide. To control *P. infestans* and to protect the potato crop, potato plants are sprayed preventively with fungicides. Therefore, successful production of healthy potato crops relies on repeated applications of several fungicides during the potato growing season. Due to a restrictive government policy on the use of pesticides, the use of tin based fungicides was prohibited since 2005 in Belgium. These tin based contact fungicides were characterized by a good rainfastness and eradicant activity.

The purpose of this study was to evaluate combinations of fungicides commonly used to control late blight and to investigate the curative and eradicant action of these fungicide combinations for the control of foliar and tuber blight in order to replace tin based fungicides.

Material & Methods

Field trial

A field experiment was carried out on the experimental farm of the 'University College Ghent' at Bottelare during the growing season 2005. Several fungicide combinations (Table 1, table 2) were compared in a spray system based on 3-day intervals to test their curative and eradicant action. Therefore an artificial inoculation was done before the test period was started. The experiment was set up with the variety 'Bintje'. Treatments were carried out with a AKZO sprayer to 3 m wide and 12 m long plots. The spray boom was equipped with TeeJet nozzles (Teejet XR 11003 VK) spaced 50 cm apart. The water volume was always 300 l/ha.

Table 1: Fungicides used in the field trial 2005.

Commercial product	Active matter
Ranman	80 g/ha cyazofamide + 126,9 g/ha heptamethyltrisiloxane
Shirlan	200 g/ha fluazinam
Valbon	28 g/ha benthiavalicarb-isopropyl + 1120 g/ha mancozeb
Acrobat	0,12 kg/ha dimethomorph + 1,07 kg/ha mancozeb
Mixanil	100 g/ha cymoxanil + 750 g/ha chlorothalonil
Tattoo C	0,938 kg/ha propamocarb + 0,938 kg/ha chlorothalonil

Table 2: Fungicide applications.

Treatment	Object 1	Object 2	Object 3	Object 4	Object 5	Object 6	Object 7	Object 8	DSS	Control
1	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb
2	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb	mancozeb
3	Ranman + Valbon	Ranman + Acrobat	Ranman + Mixanil	Ranman + Tattoo C	Shirlan + Valbon	Shirlan + Acrobat	Shirlan + Mixanil	Shirlan + Tattoo C	Tattoo C	untreated
4	Ranman + Valbon	Ranman + Acrobat	Ranman + Mixanil	Ranman + Tattoo C	Shirlan + Valbon	Shirlan + Acrobat	Shirlan + Mixanil	Shirlan + Tattoo C	Acrobat	untreated
5	Ranman + Valbon	Ranman +Acrobat	Ranman + Mixanil	Ranman + Tattoo C	Shirlan + Valbon	Shirlan + Acrobat	Shirlan + Mixanil	Shirlan + Tattoo C	Acrobat	untreated
6	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	untreated
7	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	Shirlan	untreated
8	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	untreated
9	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	Ranman	untreated

The experimental design was a fully randomised block design with 4 replicates. The fungicide treatments were randomised within the blocks.

Following crop husbandry measures were taken: planting date of certified seed potatoes: 22 April 2005; row distance: 0.68 m; fertilisation: in autumn 18 ton digested dung, in spring 120 kg/ha N, 100 kg/ha P_2O_5 and 160 kg/ha K_2O and a second fraction of N 148 kg/ha. Herbicide treatment: linuron + pendimethalin + prosulfocarb: 675 g + 800 g + 3,2 kg/ha (Afalon 1,5 l/ha + Stomp 2 l/ha + Defi 4 l/ha); control of chicory volunteer plants: rimsulfuron + isodecyl-alcohol ethoxylaat: 10 g/ha + 90 g/100 ml (Titus 40 g/ha + Trend 100 ml/100 l water).

Inoculum production and foliage inoculation

A mixture of 2 isolates of *P. infestans* was used for artificial infection. Inoculum was produced by the following procedure: sporangia were washed from sporulating lesions on detached leaflets of the susceptible potato cultivar 'Bintje' by rinsing the lesions with chilled distilled water + 0.01 % Tween and adjusted to 10^4 sporangia per ml using a Bürker counting

chamber. To release zoospores, the resulting sporangial suspension was chilled for 1.5 h at 6 °C prior to inoculation. Plants of the mid rows (4 plant/row) of each experimental plot were inoculated by spraying ~ 26 sporangia/plant on 28 June in the late afternoon. In total 80 plants were infected with *P. infestans*. Before inoculation and 15 h after inoculation, the plants were sprayed with water to create optimal humidity conditions for infection. Due to high temperatures with daily average temperatures above 20 °C and low humidity the *P. infestans* infection was not successful. The plants were inoculated again on 13 July. Between 13 July and 23 July the mean temperature fluctuated between 15.5 and 20.4 °C and 10 mm of rain was fallen. Those weather conditions favoured the development of *Phytophthora* infections all over the plots.

Fungicides and concentration

The fungicides used in this field experiment were commercial formulations of systemic and protectant fungicides. Eight fungicide combinations were studied and the Flemish decision support system advised to spray the potato crops with 0,938 kg + 0,938 kg/ha propamocarb + chlorothalonil (Tattoo C) and twice with 0,12 kg + 1,07 kg/ha dimethomorph + mancozeb (Acrobat) according to the predominating weather conditions (Table 2). Fungicide applications began 2 weeks after emergence and are summarized in table 2. The first treatments were the same for all objects: all plots were sprayed with mancozeb: 1 kg/ha (Mancomix 3 kg/ha) on a weekly basis to protect foliage from natural infection by *P. infestans*. With the appearance of the first disease symptoms, the plots were 3 times treated with the different fungicide combinations at 3-day intervals (Table 2). After the last application the experimental fields were sprayed twice on a 7-day basis with 200 g/ha

fluazinam (Shirlan 0,4 l/ha) and twice with 80 g/ha + 126,9 g/ha cyazofamide + heptamethyltrisiloxaan Ranman A 0,20 l/ha + B 0,15 l/ha).

Diquat 600 g/ha (3 l/ha Reglone, Zeneca) was used to dessicate leaves and stems. During the growing season foliage destructions were also carried out in plots which were infected for 50 % and more to limit the epidemic pressure.

Disease estimates

To measure the intensity of foliage blight caused by *P. infestans* the assessment key of Cox & Large (1960) was used: 0.0 % blight: no disease observed; 0.1 %: a few scattered plants blighted, no more than 1 or 2 spots in 10-m radius; 1 %: up to 10 spots per plant, or general light infection; 5 %: about 50 spots per plant, up to 1 in 10 leaflets infected; 25 %: nearly every leaflet infected, but plants retain normal form, plants may smell of blight, field looks green although every plant is affected; 50 %: every plant affected and about 50 % of leaf area destroyed, field appears green, flecked with brown; 75 %: about 75 % of leaf area destroyed, field appears neither predominantly brown nor green; 95 %: only a few leaves on plants, but stems green; 100 %: all leaves dead, stems dead or dying.

The overall amount of percentage blight was assessed at regular intervals for the middle and outer rows of plot separatly.

Data were analysed by performing analysis of variance (SPSS11.0). The One-sample Kolmogorov-Smirnov test was used to analyse the normal distribution of the obtained results. The Duncan test was used to compare treatment means.

Harvest

Tubers were harvested mechanically. Two rows over a distance of 10 m were harvested from the centre of each plot. All tubers were washed, weighed after grading and assessed for blight within 8 days after harvest. Washed tubers were examined visually for the presence or absence of lesions symptomatic of late blight. Furthermore, infected tubers were cut longitudinally to confirm the presence of dry brown corky rot in the tuber beneath the lesion, a symptom typical of late blight tuber infection. The diagnosis of tuber blight was further confirmed by observing sporangia production after incubating tubers with characteristic lesions in plastic containers containing moist paper towels. The amount of blighted tubers was defined as the rotten tubers (but due to the bacterial rot no characteristic blight symptoms could be observed) plus the tubers visually clearly infected by *P. infestans*.

Results & Discussion

The incidence of foliage blight was scored on 1, 8, 12, 23 and 29 August and on 5 September (Fig. 1). The field experiment in 2005 indicated that all the tested fungicide combinations had a significant suppressive effect on established epidemics compared to untreated plots. The differences in control efficiency for the fungicides tested were rather small and statistically not significant. No treatment was able to stop the infection and even in the sprayed plots the infection level increased above the 50 %. Just for the first treatment with the fungicide combinations the grade of foliar blight was comparable for all the plots: meanly 128 leaf lesions were observed per plot. The first disease symptoms appeared in the middle rows and the development of leaf blight was investigated in the middle and the outer rows. The

combinations with dimethomorph + mancozeb (Acrobat) and the combination fluazinam (Shirlan) + benthiavalicarb-isopropyl + mancozeb (Valbon) gave a lower foliage protection. For fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) the degree of *Phytophthora*-infection was lower in the middle rows than for the other tested combination. And for fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) late blight developed slower in the outer rows compared to the other treatments.

No significant differences in total yield were observed for the different treatments applied (Table 3). A lower tuber yield was observed for the untreated plots: 50,5 ton/ha. The average tuber yield fluctuated between 54,8 and 61,4 ton/ha and the mean yield of all treatments was 56,1 ton/ha. The combination fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) had the highest yield: 61,4 ton/ha. The control had a significant lower graded (+35 mm) yield: 41,2 ton/ha (Table 3). A significant higher graded yield was observed for the fungicide combination fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil): 53,1 ton/ha. The

Table 3. Influence of the fungicide combinations applied on tuber yield and tuber blight in 'Bintje' during the growing season 2005.

Treament	total yield ton/ha	yield +35 ton/ha	% diseased tubers
Ranman + Valbon	52,9[a]	45,3[ab]	8,5[a]
Ranman + Acrobat	55,5[a]	47,3[ab]	5,0[a]
Ranman + Mixanil	55,5[a]	44,8[ab]	7,3[a]
Ranman + Tattoo C	59,6[a]	50,0[ab]	6,5[a]
Shirlan + Valbon	57,3[a]	49,1[ab]	5,3[a]
Shirlan + Acrobat	54,8[a]	46,6[ab]	7,0[a]
Shirlan + Mixanil	61,4[a]	53,1[a]	7,5[a]
Shirlan + Tattoo C	57,1[a]	48,4[ab]	10,8[ab]
Tattoo C - Acrobat - Acrobat	56,6[a]	47,0[ab]	8,1[a]
Onbehandeld	50,5[a]	41,2[b]	17,0[b]

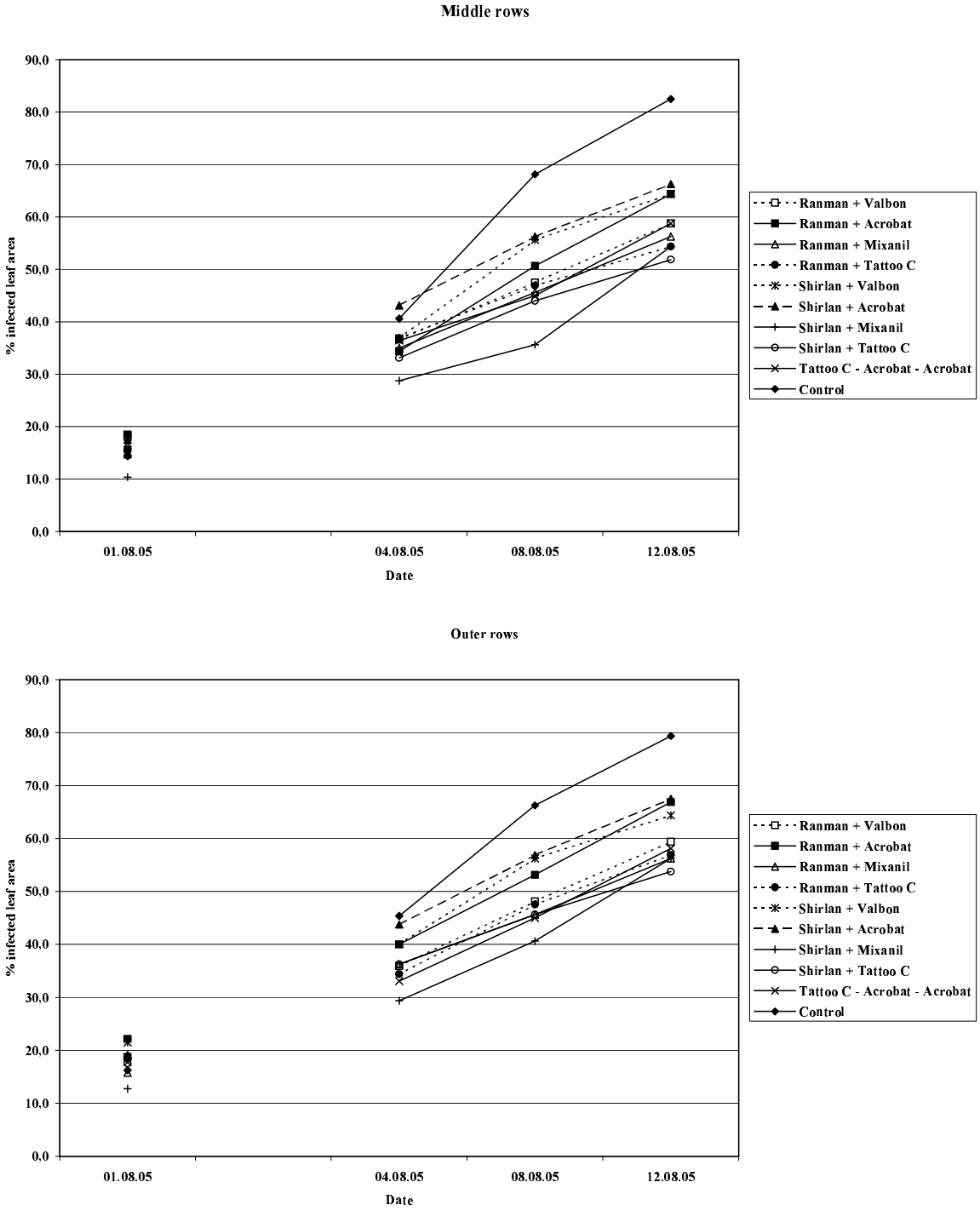

Figure 1. Influence of the fungicide combinations applied on the infection level of late blight of 'Bintje' during the growing season 2005.

graded yield of the different treatments fluctuated between 53,1 en 44,8 ton/ha en the mean yield of all treatments was 48,1 ton/ha compared to 47,0 ton/ha for the plot sprayed according to the advice of the decision support system (0,938 kg + 0,938 kg/ha propamocarb + chlorothalonil (Tattoo C) and twice with 0,12 kg + 1,07 kg/ha dimethomorph + mancozeb (Acrobat)). The combination fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) had a good foliage protection as well as the highest yield.

The percent tuber rot was significantly higher for the control and fluazinam (Shirlan) + propamocarb + chlorothalonil (Tattoo C), respectively 17 and 11 % (Table 3). The amount of diseased tubers was significantly lower for the other fungicide treatment tested: the amount of infected tubers fluctuated between 5,0 and 10,8 %. The mean percent tuber blight was 7,2 % compared to 8,1 % for the plots sprayed according to the advice of the decision support system (0,938 kg + 0,938 kg/ha propamocarb + chlorothalonil (Tattoo C) and twice with 0,12 kg + 1,07 kg/ha dimethomorph + mancozeb (Acrobat)).

Conclusions

The growing season 2005 was characterized by high temperatures in the second part of June (daily average temperature above 20 °C) and severall rain showers from the end of June till the first week of July (in ten days 117 mm rain). In Augustus the weather was cloudy, rather cold and a lot of rain: the mean temperature was 16,5 °C and 85,4 mm rain. These weather conditions were very favourable for late blight.

Taking into account all the parameters evaluated (disease incidence, tuber yield, tuber blight) fluazinam (Shirlan) + cymoxanil + chlorothalonil (Mixanil) protected the potato crop slightly better then the other fungicide combinations tested under the environmental conditions of the trial in 2005. But the differences were small and statistically not different.

Acknowledgements

This work was carried out with the financial support of BASF, BAYER, BELCHIM, CERTIS, PROTEX and SYNGENTA.

References

Cox, A. E., and Large, E. C., 1960. Potato blight epidemics throughout the world. U.S. Dep. Agric. Agric. Handb. 174 pp.