Reduced fungicide input in late blight control (REDUCE 2007-2011) –Preliminary results from 2007 to 2009

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SUMMARY
Preliminary results from potato late blight experiments in Norway during 2007 to 2009 are presented. Field trials with fungicide doses adjusted to host resistance and late blight risk showed that it is possible to reduce the fungicide input to about 40 to 60% of the recommended dose in a cultivar with high resistance to late blight. Pot trials with silt and light clay soil and different irrigation regimes showed that most of the inoculum is not washed down into the soil, but remains in the top soil. Trials with tubers harvested at different maturity levels and inoculated with late blight spores showed no clear difference in susceptibility to tuber blight between the maturity levels. Field trials harvested at four successive dates where one half of each sample were dipped in chlorine showed that most of the tuber infections happened at harvest and not during the growing season.

KEYWORDS:
Phytophthora infestans, resistance, fungicide, tuber blight

INTRODUCTION
Potato late blight caused by *Phytophthora infestans* is an important disease in Norway. In average the potato area is sprayed 5.6 times to protect against late blight (Sætre *et al.* 2006). Some of the potato cultivars grown in Norway have moderate to high resistance to late blight in the haulm and tubers. It is possible to exploit host resistance to reduce the use of fungicides to control potato late blight (Nærstad *et al.* 2007), however this is not a normal practice in Norway. Reduced fungicide input in late blight control is a part of the project 'Reduced pesticide loads and risks in cropping systems' (REDUCE 2007-2011). In this project one of the goals is to develop models and best management practices to facilitate a good late blight control with minimal fungicide input. Preliminary results from experiments from 2007 to 2009 are presented.

MATERIALS AND METHODS

Exploiting host resistance in the haulm to reduce the fungicide input.

Field trials with inoculated spreader rows were conducted at two locations (Rygge and Solør) in 2008 and 2009. The field trials were designed as block trials with three replications with spreader rows on both sides of each block. The spreader rows consisted of an unprotected late blight susceptible cultivar (Mandel) inoculated with a spore suspension of *P. infestans* in the first half of July. Three potato cultivars with different resistance to late blight in the haulm and moderate resistance to late blight in the tubers were tested in combination with different fungicide doses. The cultivars used were Asterix (3 - 7) (resistance in the haulm and tubers on a scale from 1 to 9 where 9 is the most resistant), Saturna (5 - 6) and Peik (7 – 7). The fungicide Shirlan (fluazinam 500g/l) was applied preventively at the same times for all the treatments. Timing of the fungicide applications were done according to a new late blight model at www.vips-landbruk.no (Nærstad *et al.* 2009). The protection period of each application was 5-7 days, 5 days protection period if there were 4 or more blight risk days since last application. The three different treatments were: 1) untreated control, 2) full dose of the fungicide and 3) adjusted fungicide dose according to host resistance and late blight risk.

Table 1. *Rules used to adjust the fungicide dose to host resistance and late blight risk.*

Cultivar (resistance to late blight in the haulm, scale 1-9, 9 is the most resistant)	Number of blight favorable days (today and tomorrow) at www.vips-landbruk.no	Consecutive days with more than 1 mm rain the next 5 days at www.yr.no	Dose (% of recommended dose)
Asterix (3)	1	0-1	75
		2 or more	88
	2	0-1	100
		2 or more	100
Saturna (5)	1	0-1	50
		2 or more	75
	2	0-1	75
		2 or more	100
Peik (7)	1	0-1	25
		2 or more	50
	2	0-1	50
		2 or more	75

Wash down of spores into soil

Pot experiment with two different soil types (silt and light clay) and three different irrigation regimes (5, 10 and 15 mm of water) were conducted in 2007 and 2008. The soils were inoculated with two different inoculum doses, low inoculum dose (20 ml of 3.75 spores/ml) and high inoculum dose (20 ml of 37500 spores/ml) which were sprayed on the top of 1.5 liter pots with soil. The experiment had 3 replicates and negative controls. Soil samples were taken from the top surface and from 4 cm depth from each pot and tested with a bioassay (Lacey 1965). In the bioassay each soil sample was mixed with water and distributed on the top of 10 potato slices (approx 7 mm thick). These 10 potato slices and a negative control, without soil, were incubated in the dark at 16°C on a metal grid in a humid box. The potato slices were cut into octants after one day of incubation. The frequency of octants with *P. infestans* sporangiophores were recorded after 7 additional days of incubation at 16°C in the dark.

Tuber blight resistance at different maturity

In 2008 and 2009 three cultivars with different level of tuber resistance were grown in a field in an area of Norway with low blight risk. Tubers were harvested every second week from the beginning of August to the middle of September. Each time 60 plants of each cultivar were harvested. One to two days after harvest the tubers were washed and used for the experiment. For each cultivar the harvested tubers were divided into ten experimental units. Five units were artificially wounded by rolling the tubers over a group of 10 pins, 1 mm high, 1 cm apart, pointing upwards from a wooden base. The tubers from each unit were put into a plastic bag and spray inoculated with 20 ml of a spore suspension (10000 spores/ml in 2008, and 5000 spores/ml in 2009). Before inoculation the spore suspensions were chilled for 2 hours at 4°C to induce zoospore release. Four independently made spore suspensions were used to infect each of the units of both wounded and unwounded tubers. The last two units, one wounded and one unwounded were used as non inoculated controls. The tubers were mixed in closed plastic bags for half a minute and incubated at 16°C in the dark for one day. The bags were cut open to let the tubers dry and incubation of the tubers was continued for three weeks further at 16°C in the dark. Then the number of tubers with blight was recorded.

Tuber blight field trials

Field trials were conducted at two locations in 2008 and 2009. The fields were artificially inoculated by spraying all the plants with a spore suspension in the first half of July. The field trials had three replications and had a split plot design, with or without irrigation at critical dates on the whole plots and three cultivars with different level of resistance to tuber blight on the subplots. The critical dates were defined as days with a lot of inoculum produced in the haulm (sum of attached and released viable spores calculated according to New Late Blight Model (Nærstad unpublished data)) and no rain according to the weather forecast from The Norwegian Meteorological Institute. Each trial was irrigated on a critical day with 5 mm of water on one or two occasions in the season. Tubers were harvested four times (from ten plants per plot), approximately every second week from the end of July/beginning of August to September. The tubers from each plot were harvested into a net and kept dry. In 2009 the sample from each plot were split in two nets. One of the two nets was dipped in a chlorine solution (1% NaOCl) immediately after harvest. The number of blighted tubers was recorded after dry incubation in the dark at 16°C for 3-4 weeks.

RESULTS AND DISCUSSION

Exploiting host resistance in the haulm to reduce the fungicide input.

The weather was very blight favorable in August 2008 and in the end of July and beginning of August in 2009. In the unprotected control plots late blight killed the haulm in the end of August at both locations in 2008. In 2009 the haulm was also totally killed at Rygge in the end of August but some green leaves remained at the end of the season at Solør. Some blight developed in the plots treated with fungicide, but not significantly more in the treatments with fungicide dose adjusted to host resistance and late blight risk than in treatments with full fungicide dose. In these four field trials it was possible to reduce the fungicide use with 6-19% for the cultivar with low resistance (Asterix), 17% - 36% for the cultivar with medium resistance (Saturna) and 42%-61% for the cultivar with high level of resistance (Peik). These results are affected both by the rules used for adjusting the doses and also the actual weather conditions during the experimental period. However, the experimental results confirm earlier data (Nærstad *et al.* 2007) that there is a potential of reducing the fungicide input by exploiting the host resistance.

Wash down of spores in soil

The surface soil inoculated with high inoculums dose gave almost 100 % infections of the octants after 5 and 10 mm of irrigation and about 96% infection at 15 mm of irrigation. The surface soil with low inoculum dose gave approximately 10%, 8% and 2% infection at 5, 10 and 15 mm of irrigation respectively. A very small proportion of the inoculum was washed down to 4 cm depth, and there was a tendency that more spores were washed down at high amounts of irrigation water. Soil samples taken at 4 cm depth from soil with high inoculum level gave approximately 12%, 9% and 15% infection at 5, 10 and 15 mm of irrigation respectively. Samples from 4 cm depth in the soil with low inoculum dose gave no infections in the bioassay. There were no significant differences between data from the two soil types in this experiment.

Tuber blight resistance at different maturity

There was no clear trend in the effect of maturity on the tuber blight infections. In 2008 almost all the wounded tubers of Kerrs Pink became infected, and approx. 90 to 95% of the unwounded tubers became infected. About 85 to 95 % of the wounded Saturna tubers were blighted and about 60 to 90% of the unwounded tubers were infected. The wounded Troll tubers got approx. 75 to 90 % blighted tubers and the unwounded got approx. 35 to 70% blighted tubers. In 2009 the experiment was disturbed by pink rot (*Phytophthora erythroseptica*) infections.

Tuber blight field trials

There was no significant effect of irrigation at critical days on tuber blight. At Rygge the disease developed fast both in 2008 and 2009 and the haulm was killed by late blight by the middle of August. At Solør almost all the haulm was attack by late blight by the end of August in 2008 and 2009. In 2008 some tuber blight developed at all harvest dates, but more blight developed on the first dates than on the last dates. Hence, most of the tuber infection must have happened at harvest and not in the growing season. In 2009 we dipped half of each sample in chlorine immediately after harvest to be able to distinguish between infection in the growing season and at harvest. Tubers dipped in chlorine developed hardly any tuber blight. Tubers not dipped in Chlorine developed much more tuber blight on the first two harvests than on the last two harvest dates. On the two last harvest dates both years the haulm was totally killed by late blight.

CONCLUSIONS

The experiments confirm that it is possible to reduce the fungicide input in late blight control by exploiting the host resistance to reduce the fungicide dose. By using the rules in Table 1 it was possible to reduce the fungicide input in these four inoculated field trials by about 40 to 60% in the cultivar with high resistance without increasing the level of infection in the haulm compared to the treatment with full dose.

Most of the *P. infestans* inoculum remain in the top soil and less than 0,1% of the inoculum is washed down to 4 cm depth in soil without cracks.

No clear evidence was found in 2008 that tubers became less susceptible to tuber blight infection at increasing maturity .

In the four tuber blight field trials the tuber blight was mainly caused by infection at harvest.

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