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USEFULNESS OF FUNGICIDES WITH VARIOUS MODES OF ACTIONS IN THE PROTECTION OF POTATO CROPS

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Abstract: In Poland, about sixty fungicides are registered for chemical protection of potato crops against late blight (*Phytophthora infestans*) and some of them are effective against early blight (*Alternaria* spp.). Time of appearance of pathogens in potato crops depends on climatic conditions. In Bonin climatic conditions in the years 1998–2002, early blight was observed at the earliest date i.e. 41–56 days after potato planting. Trials carried out at the Plant Breeding and Acclimatization Institute Bonin have shown different usefulness of fungicides in control of some pathogens of potato. The tested fungicides varied in their mobility (contact, translaminar, systemic) and activity against pathogens (protectant, curative, eradicative). All tested fungicides were effective in control of late blight in potato crops. They inhibited the rate of late blight development and in most cases the differences of their effectiveness were not significant. Systemic fungicides with slower mobility have the best efficacy in control of late blight infections occurring on potato stems. In laboratory tests, mancozeb, propineb and mixture of metalaxyl and mancozeb were significantly more effective in inhibiting the development of *Alternaria*. Fungicides, which are effective in the control of different pathogens, are particularly useful in potato protection programs.

Key words: potato, diseases, chemical protection, fungicides

INTRODUCTION

Diseases occurring during the growing season and in storage are factors causing high losses in potato yield worldwide. Yield of healthy and storable tubers can be obtained when provided with good protection of potato plants that comprises various factors regarding both occurrence of pests and plants.

Chemical protection of potato crops during the growing season is one of the basic methods of integrated protection management. Both timing of the start of protection and selection of fungicides are key in chemical protection.

Predicting the date of pathogen occurrence and decision support systems aim at determining the risk of disease outbreak, date of the first and following fungicidal treatments and the most suitable intervals between sprays. Those fungicides selected for chemical protection should provide satisfying efficacy in pathogen control in accordance with growth stages of potato plants. Efficient protection treatments can either reduce disease incidence at the beginning of the season or decrease disease development throughout the growing season (Zadoks & Schein 1979). It has been accepted that 5% of destruction of aboveground parts of potato plants by late blight (casual agent *Phytophthora infestans*) can lead, under favourable conditions, to rapid disease development and result in total crop destruction within 7–14 days (Large 1958).

For many years at the Plant Breeding and Acclimatization Institute Bonin various studies have been carried out on the evaluation of numerous factors affecting efficient protection of potato crops against major diseases. The long-term observations have confirmed that the most important pathogens occurring on potato crops are *P. infestans, Alternaria* spp. and *Rhizoctonia solani*. Various forms of diseases caused by these pathogens, time of their occurrence as well as disease incidence, are in large extent dependent upon weather conditions and changes within pathogen populations (Kapsa & Wojciechowska-Perz 1996; Kapsa 2001; Osowski 2001). The changes within pathogen populations have a considerable influence on applied chemical protection (Kapsa & Osowski 1999; Kapsa 2000).

MATERIAL AND METHODS

All observations and investigations were conducted at the Plant Breeding and Acclimatization Institute Bonin in the years 1998–2002.

Evaluation of time of occurrence of the most important pathogens was based on weekly observations performed on naturally infected potato plants of an unprotected collection of potato cultivars and started just after plant emergence. Dates of first occurrence of symptoms for a particular disease were recorded.

Studies on efficacy of fungicides with different types of mobility in late blight control were carried out in field experiments on mid-late cv. Rywal. The following fungicides were under investigation:

- contact fungicides: fluazinam (Altima 500 SC) at a dose of 0.4 l/ha and mancozeb (Dithane M-45 80WP) at a dose of 2.0 kg/ha
- translaminar (= local penetrant) fungicides: cymoxanil + mancozeb (Curzate M 72,5 WP) at dose of 2.0 kg/ha
- systemic fungicides: metalaxyl M + mancozeb (Ridomil Gold MZ 68 WP) at a dose of 2.0 kg/ha and propamocarb-hydrochloride + chlorothalonil (Tattoo C 750 SC) at a dose of 2.0 l/ha.

Potato protection against the late blight began with the occurrence of the very first symptoms of the disease on the experimental plots and was carried out until the end of the first decade of August. The number of applications depended upon infection pressure of the pathogen and fungicide type and was within a range from 4 to 7. The criteria for protection effectiveness were disease incidence at the end of growing season, the late blight development rate (according to Van der Plank 1963) and time of delay for 50% of haulm destruction.

In greenhouse conditions, experiments on protection efficacy against the late blight occurring on stems of cv. Ruta inoculated with the pathogen were carried out. Applied fungicides had different modes of actions i.e. chlorothalonil (Bravo 500 SC), propamocarb-hydrochloride + mancozeb (Tattoo 550 SC) and metalaxyl + mancozeb (Ridomil MZ 72 WP).

The fungicides were applied 7 and 2 days before artificial infection, as a preventive treatment, and on the day the infection was done, and 2 days after infection. Plants were infected by spraying the whole potato plant with 10 ml of suspension of *P. infestans* (concentration 25 conidia per 1 mm^3). The observations were carried out over 4 weeks and each time the number of lesions on stems was recorded. The control plants were plants infected with the fungus but not protected with fungicide treatment.

Evaluation of efficacy of selected fungicides in control of potato early blight was performed in laboratory conditions. Three series of tests on PDA Petri dishes containing tested fungicides (at doses as recommended for protection) were set up. In potato early blight control were compared chlorothalonil (Bravo 500 SC), mancozeb (Dithane M 45 80 WP), propineb (Antracol 70 WP), metalaxyl as technical product, and metalaxyl + mancozeb (Ridomil MZ 72 WP), propamocarb-hydrochloride (Previcur 607 SL) and propamocarb-hydrochloride + mancozeb (Tattoo 550 SC). A disk (diam. 5mm) of a 2-week old fungus colony was placed on the medium's center and every 3 days measurements of the diameter of the fungus colony were taken. For comparison of tested products' efficacy in inhibition of fungus growth the size of a fungus colony after 15 days was analyzed.

The results of investigations on fungicide efficacy were subjected to analysis of variance.

RESULTS AND DISCUSSION

Each year the most important potato diseases appear at different time due to weather conditions that in larger or smaller extent affect pathogen occurrence (Tab. 1). Six-year observations conducted at Bonin revealed that potato early blight was recorded the earliest i.e. 41–55 days after planting. Late blight was noted generally later and depended on the place of occurrence of the very first symptoms. The first symptoms of late blight on leaves were recorded from 42 to 81 days after planting (DAP) while on stems 54 to 81 DAP. The year 1999 was an exception as potato early blight and both forms of late blight appeared almost at the same time (51, 57 and 54 DAP, respectively).

Table 1. Dates of appearance of main pathogens in potato crops – days after planting (Bonin, years 1997–2002)

Disease	Years					
	1997	1998	1999	2000	2001	2002
Early blight	55	41	51	48	42	48
Late blight on potato leaves	57	62	57	81	42	56
Late blight on potato stems	68	71	54	81	63	63

In Poland there are about 60 fungicides registered for potato protection against casual agents of diseases. The control of particular pathogen or a certain form of the pathogen should rely on the choice of the most suitable product.

The field experiments carried out in the years 1998–2002 at PBAI Bonin proved satisfactory efficacy of tested fungicides in control of late blight. The evaluated products differed with mobility (contact, translaminar, systemic) and mechanism of action (protectant, curative, eradicative) – Table 2. All fungicides showed good efficacy in the control of late blight compared with the untreated control (Fig. 1). The efficacy of control with particular fungicide measured by calculation of late blight development rate depended on weather conditions to a high degree. There were some differences among late blight development rates in the treatments however, in most cases they were insignificant. The year 2000 was the exception due to high infection pressure of the pathogen. In this year, the effectiveness of active in-

Table 2. Characteristic of activity of tested fungicides In Bain (2002)

Fungicide	Mobility	Activity *		
		protectant	curative	eradicative
fluazinam	contact	+++	0	0
mancozeb	contact	++	0	0
cymoxanil	translaminar	++	++	+
propamocarb	systemic	++(+)	++	++
metalaxyl	systemic	++(+)	++(+)	++(+)

* 0 = no effect, + = reasonable effect ++ = good effect, +++ = very good effect

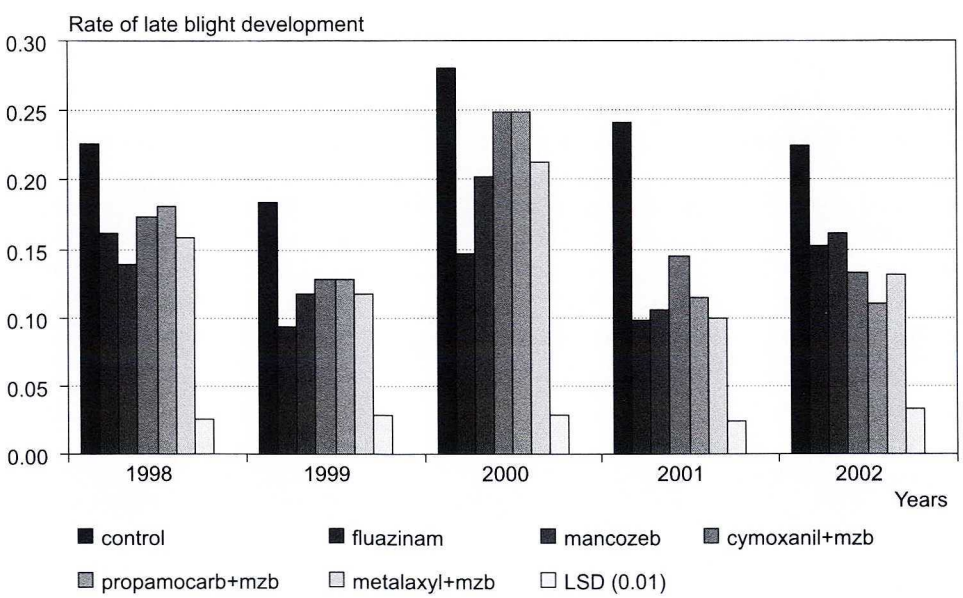

Fig. 1. Effectiveness of fungicides with various mobility in inhibition of late blight development in potato crop

gredient fluazinam was definitely better than other products. In 2002, the mix of propamocarb with chlorothalonil provided significantly better efficacy than two other contact fungicides.

The conducted earlier studies on fungicide efficacy in control of late blight occurring on potato stems showed various usefulness of their application (Kapsa 2001). The results from greenhouse and field investigations revealed that the most efficient fungicides in control of late blight of stem form were those that had systemic mobility and were applied preventively, for example mix of propamocarb-hydrochloride with chlorothalonil or metalaxyl with mancozeb (Fig. 2). Under extreme conditions, the mix propamocarb with mancozeb can be used for late application i.e. 2 days after pathogen infection. However, the efficacy of this late treatment was not as good as treatment before the pathogen infection. The best stem protection against *P. infestans* infection can be obtained with preventive treatment before occurrence of disease symptoms on a plant. Schlenzig et al. (1999) using the ELISA test defined the infection of the pathogen in stems 39 days before first symptoms of the disease were found on plants.

The efficiency of systemic fungicides in protection of stems against late blight infection relies also on the translocation rate of the product to other plant organs. Comparative studies conducted at the Experimental Station at Chesterford Park (Harris – personal information) regarding two active ingredients propamocarb and ofurace (phenylamide) showed different translocation rates of these compounds

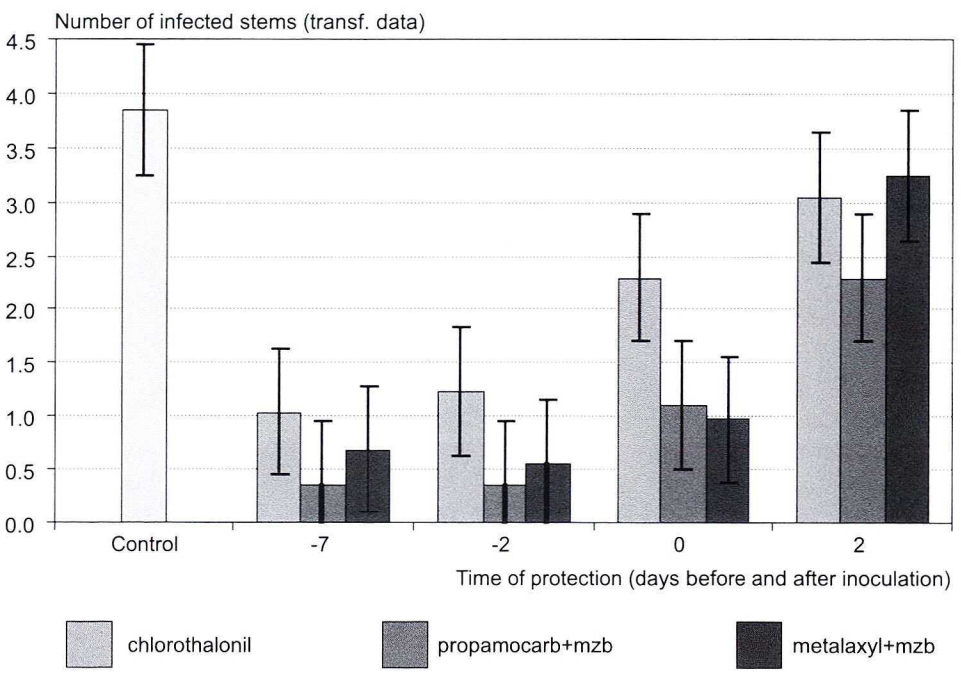

Fig. 2. Differences in efficacy of controlling of late blight infections occurring on potato stems – greenhouse experiments

through a plant. Both active ingredients labeled with radioactive carbon were applied into a base of potato stem. After 9 days, the taken measurements showed that ofurace accumulated in leaves while propamocarb was still present in large amounts in stems. Better efficiency of potato protection against late blight of stem form with products containing propamocarb that was observed at Bonin could be due to slower translocation of this active ingredient through plants.

The fungicides containing mancozeb, propineb and mix of metalaxyl with mancozeb showed the best efficacy out of 8 products tested in laboratory conditions in the inhibition of fungus growth of *Alternaria* spp. Metalaxyl and propamocarb-hydrochloride applied separately did not provide significant efficacy in the inhibition of mycelial growth (Fig. 3).

Based on long-term results regarding time of occurrence of the most important fungal pathogens in potato crops and efficacy of various fungicides a scheme can be set up of the most suitable potato protection. The protection can take two forms, an intensive based on phenological phases of a given crop that comprises routine fungicidal applications and evaluated risk of disease occurrence, or sustainable protection based on pathogen monitoring and decision support systems.

The intensive protection is recommended for potato crops identified as being of high risk of disease outbreak, particularly late blight, for susceptible cultivars and for crops where additional sources of casual agents of the diseases is present (adjacent fields with early cultivars).

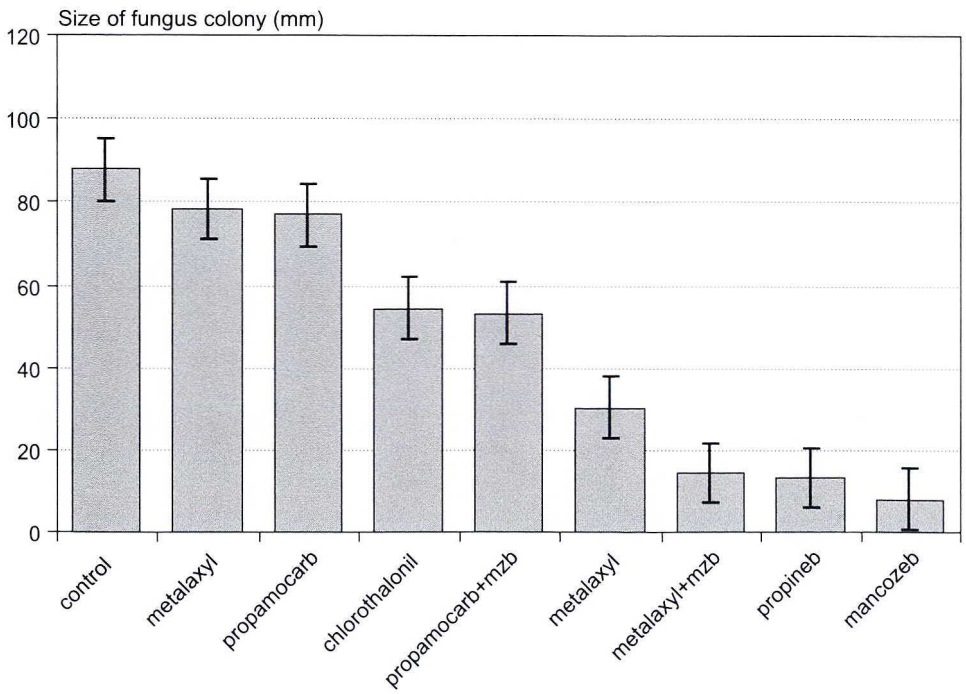

Fig. 3. Efficacy of fungicides in inhibition of growth of *Alternaria* in laboratory tests

The sustainable protection relies on pathogen monitoring and decision support systems. The criteria for the start of protection are data on epidemiology of casual agents, weather conditions, infection pressure of pathogens as well as information on a given crop i.e. cultivar resistance and time of plant emergence. The previous studies carried out in Poland showed that protection performed according to forecasting of pathogen occurrence resulted in a decrease number of chemical treatments, on average 2–4 applications (Wójtowicz & Piekarczyk 1998; Kapsa 2002).

In this protection program, it is recommended to apply fungicides that are efficient in control of various pathogens that occur at the same time. The control of first infection of the late blight appearing on leaves can be achieved with products that are also efficient in controlling potato early blight (mancozeb, propineb). During intensive growth of potato plants for the protection against late blight stem form and early blight systemic fungicides containing mancozeb are recommended as well, particularly those that are more slowly translocated through a plant.

CONCLUSIONS

1. Time of pathogen occurrence on potato crops in a given year depends mainly upon weather conditions. At Bonin potato early blight was found the earliest 41–55 days after planting.
2. Five-year investigations carried out at Bonin revealed that in most cases the differences in efficacy of fungicides with different mobility in control of late blight in potato crops were insignificant.
3. The systemic fungicides, particularly those that can be translocated more slowly through a plant are the most efficient in controlling stem type of late blight.
4. In laboratory conditions mancozeb, propineb and mix of metalaxyl with mancozeb showed significantly better efficacy in inhibition of development of the fungus *Alternaria* spp.
5. The fungicides that are efficient in controlling various pathogens occurring at the same time are the most suitable products recommended in protection program for potato crops.

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POLISH SUMMARY

PRZYDATNOŚĆ FUNGICYDÓW O RÓŻNYCH MECHANIZMACH DZIAŁANIA W OCHRONIE PLANTACJI ZIEMNIAKA

W Polsce zarejestrowanych jest około sześćdziesięciu fungicydów do ochrony plantacji ziemniaka przed zarazą (*Phytophthora infestans*). Część z nich zarejestrowana jest także do zwalczania alternariozy (*Alternaria* spp.). Termin wystąpienia patogenów na plantacjach ziemniaka w danym roku zależy w znacznym stopniu od układu warunków meteorologicznych. W Boninie (lata 1998–2002) najwcześniej występowała alternarioza (41–55 dni po posadzeniu ziemniaków). Doświadczenia wykonane w IHAR w Boninie w ostatnich latach wykazały różną przydatność fungicydów w zwalczaniu różnych patogenów ziemniaka. Testowane fungicydy różniły się swoją mobilnością w roślinie (powierzchniowe, wgłębne, układowe) i aktywnością w stosunku do patogenów (zapobiegawcze, lecznicze, wyniszczające). Wszystkie testowane fungicydy były skuteczne w zwalczaniu zarazy na plantacjach ziemniaka. Hamowały tempo rozwoju choroby, a różnice w ich efektywności w większości przypadków nie były statystycznie istotne. W ochronie przed infekcjami zarazy ziemniaka występującymi na łodygach, najlepszą skuteczność wykazują fungicydy układowe, szczególnie te, które wolniej przemieszczają się w roślinie. W badaniach laboratoryjnych istotnie lepszą skuteczność w hamowaniu rozwoju grzyba *Alternaria* wykazały mankozeb, propineb i mieszanina metalaksylu z mankozebem. Fungicydy skuteczne w zwalczaniu różnych patogenów są szczególnie użyteczne w programach ochrony plantacji ziemniaka.