

<sup>1</sup>E. ÇAKIR, Ph.D

ORCID: 0000-0002-3984-744

<sup>2</sup>F. DEMİRCİ, Prof

ORCID: 0009-0007-6958-6029

<sup>1</sup>Directorate Institute of Plant Protection Central Research.

Gayret Mahallesi. Fatih Sultan Mehmet Bulvarı. No: 66,

06172 Yenimahalle, Ankara

<sup>2</sup>Ankara University Faculty of Agriculture Department of Plant Protection.

Ankara Üniversitesi Ziraat Fakültesi Bitki Koruma Bölümü No: 37/9,

Gümüşdere 60. Yıl Kampüsü, Gümüşdere Mahallesi, 06135 Keçiören, Ankara

e-mail: <sup>1</sup>cakir@hotmail.com, <sup>2</sup>fdemirci@agri.ankara.edu.tr

## CONTROL OF POTATO WART DISEASE (*SYNCHYTRIUM ENDOBIOTICUM*) BY FUNGICIDE SOIL TREATMENTS

---

*Synchytrium endobioticum* is the causative agent of potato wart disease and can remain in the soil for several years via its sporangia. Effective protection against this disease includes quarantine and the use of disease-resistant potato varieties. However, so far it has not been eradicated. The aim of this study was to determine the effect of fungicides for soil treatment to protect against potato wart. Experiments were conducted with propamocarb hydrochloride 722 SC g/l, metalaxyl M + fludioxonil 10 + 25 g/l, gimexazole 360 g/l, tolklofos methyl + thiram 30 + 30%, dimethomorph + cuproxy chloride 6 + 40WP, famoxadone + cymoxanil 22.5 + 30%, Mandipropamide + Mancoceb 5 + 60%, Zoxamide + Mancoceb 8.3 + 66.7% in the growth chamber and field conditions — showed that Famoxadone + Cimoxanil 22.5 + 30% is able to protect against the disease by 100% in both experimental conditions.

**potato wart disease, *Synchytrium endobioticum*; fungicides; control; soil treatments**

**Introduction.** The only cultivated host of *Synchytrium endobioticum* is potatoes, but wild *Solanum* spp. are also infected. A number of solanaceous plants, including tomatoes, can be artificially inoculated. The fungus affects the tuber initials and tubers, but not the roots. Early infection of young developing tubers results in their becoming so distorted and spongy as to be scarcely recognizable. In older tubers, only the eyes are infected; they develop into characteristic, warty, cauliflower-like protuberances; these are

initially whitish or green if exposed to light, but gradually darken and eventually rot and disintegrate. The whole tuber may be entirely replaced by the warty proliferation. Similar warts occur on stolons. Warts which develop in a potato store, i.e. in the dark, may show the same colour as the tubers skin. (Smith et al. 1997) *S. endobioticum* is an obligate soil borne Chytrid fungus. The fungus can survive approximately 30 years in the dept of 50 cm in soil (Smith et al. 1997) and can infect the susceptible hosts in this time period.

Wart control relies on the statutory measures like quarantine wart resistance remains an important element to be considered in potato breeding programmes, especially in central and Eastern Europe, (Stachewicz, 1984; Potocek & Broz, 1988). Previous chemical control studies using fungicides were usually failed. Effectiveness of Triforine, Thiophanate methyl, Carben-dazim, Carboxin, Carboxin + Captan, Thiabendazole and Benomyl applied to potato tubers were screened in greenhouse and field. Only carbendazim showed slight fungicidal effect on the disease (Hampson 1977). Hampson (1977) also indicated that the critical time for the control of the disease was the period between release of zoospores from resting sporangia and the infection of the zoospores to sprouts, stolon buds and tuber eyes of potatoes.

The eradication of the pathogen from the soil was succeeded by massive use of toxic chemicals which were highly phytotoxic (Hampson 1988). Formalin has often been tried as a soil disinfectant (Erickson, 1914, Roach et al. 1925). In cooperative eradication programs was applied in West Virginia-na, applications of formalin and copper sulphate eliminated the sporangia after 10 years (Brooks et al. 1974). Additionally mercuric chloride and Bordeaux mixture were also used effectively (Hunt et al. 1925). Roach and Glynne (1928) indicated that application of sulphure preparations caused reduction in the infection.

As biological control approach, application of *Thiobacillus thiooxydans* to soil resulted erratic results (Roach et al. 1925). Use of steam treatment to the soil also abandoned in Pennsylvania, USA, because irregularity of topography affected the efficacy (Hampson 1988). Formaldehyde was investigated as soil disinfectant for many times. Erikson (1914) applied formaldehyde to the soil as 10 l/m<sup>2</sup> two week before sowing. This application reduced the infection rate, and the results implied that formaldehyde can be used for eradication of wart disease. However Roach et al (1925) indicated that formaldehyde caused inconsistent results. Hampson (1985) examined the effectiveness of lime against to wart disease, but the results were also inconsistent.

Because of the fact that potato wart disease is a quarantine organism and its tolerance is zero, it is obligatory that exported agricultural row material should have been grown in *S. endobioticum* free soil (EU 1969, 2022). Infested areas quarantined for many years. This research was conducted in order to determine effective fungicides to eradication of sporangia of wart disease agent.

## **Materials and Method**

### **Determination of inoculum concentration of field soils.**

Soil samples were collected from infested fields according to EPPO 2003. Sporangial concentration of the soil samples were determined according to Hampson and Thompson (1977).

### **Laboratory experiments**

Soil samples which collected from selected infested areas were weighted as 2 kg The fungicides used in the trials and their suspension concentrations were given in Table 1. Each fungicide was used in two different concentrations (Concentration 1 (low) and Concentration 2 (high)). Soil samples were treated with fungicide suspensions that enough volume for drenching. Fifteen days after treatment, 45 g soil sample was applied on each potato tubers (Marabel cv.) in average 5cm diameter, located in germination vials. After the inoculation, the vials incubated for 75 days under 18°C and 85% relative humidity. The potato tubers were moistened regularly.

After the incubation for 75 days, potato tubers were removed, washed under tap water and potato sprouts were investigated for warts. Disease evaluations were done according to disease scale (PM 7/28), EPPO 2004. Disease severities were calculated by using Townsend-Heuberger formula. Effectiveness of fungicides were determined. Data were subjected to ANOVA at the  $P=0.05$  level and comparisons were done by using Duncan's Multiple Range Test.

### **Field experiments**

The fungicides that found effective *in vitro* tests, were evaluated for field performance. Two fields that contain the highest sporangial concentration were selected for the field trials. The experiments were arranged according to random block design with 4 replications. Each plot was 3 m<sup>2</sup>. Fungicides

#### **1. Fungicides that used in laboratory trials and application concentrations**

Fungicides	Concentrations g or ml/l water	
	1 (Low)	2 (High)
Propamocarb hydrochloride 722 SC g/l	3.5 ml	7 ml
Metalaxyl M + Fludioxonil 10 + 25 g/l	2.5 ml	5 ml
Hymexazol 360 g/l	3 ml	6 ml
Tolcophos Methyl + Thiram 30 + 30%	6 g	12 g
Dimethomorph + Copperoxychloride 6 + 40WP	3 g	6 g
Famoxadone + Cymoxanil 22.5 + 30%	0.4 g	0.8 g
Mandipromid + Mancozeb 5 + 60%	3.5 g	7 g
Zoxamide + Mancozeb 8.3 + 66.7%	1.8 g	3.6 g

were suspended in 100 l water and each plot were drenched with 25 l of fungicide suspensions. 15 days after the fungicide application, 10 potato tubers (Marabel cv.) were sown to each plot. Second fungicide applications were done when the plants reached to 25 cm. The third fungicide applications were done 20 days after second fungicide applications.

Evaluation of the field trials were performed during harvest and by observing tubers and by counting the tubers diseased (with warts) and healthy (without wart). The percentage of diseased tubers were calculated and the data were subjected to ANOVA at the  $P=0.05$  level and comparisons were done by using Duncan's Multiple Range Test.

### **Results and Discussion**

#### **Laboratory tests**

The first symptoms were observed on all the control tubers. After that wart developments occurred on the tubers treated with both concentration (1 and 2) of Propamocarb hydrochloride, Metalaxyl M + Fludioxonil and Hymexazol. Effects of Propamocarb hydrochloride were 55% in concentration 1 and 92.50% in concentration 2. Effects of Metalaxyl M + Fludioxonil were 75% in concentration 1 and 77.5% in concentration 2. Effects of Hymexazol were 72.5% in concentration 1 and 95% in concentration 2.

Famoxadone + Cymoxanil, Dimethomorph + Copperoxychloride, Zoxamide + Mancozeb, Mandipromid+Mancozeb and Tolclophos Methyl + Thiram totally inhibited the fungus in the soil and suppress the wart development on the potato sprouts in all concentrations (Table 2).

#### **Field Experiments**

Effects of Fungicides on disease development in the field.

The fungicides which inhibited the sporangia in the soil totally in laboratory trials were Tolclophos Methyl + Thiram, Dimethomorph + Cop-

#### **2. Effects (%) of fungicides, applications, in two different concentrations to the infected soil on the wart development on potato sprouts**

Fungicides	Effects (%)	
	Concentration 1	Concentration 2
Propamocarb hydrochloride 722 SC g/l	55±2.89a*	92.50±4.79b
Metalaxyl M + Fludioxonil 10 + 25 g/l	75±2.89b	77.5±2.5 a
Hymexazol 360 g/l	72.5±8.54b	95±2.89b
Tolclophos Methyl + Thiram 30 + 30%	100c	100c
Dimethomorph + Copperoxychloride 6 + 40g/kg	100c	100c
Famoxadone + Cymoxanil 22.5 + 30%	100c	100c
Mandipromid + Mancozeb 5 + 60%	100c	100c
Zoxamide + Mancozeb 8.3 + 66.7%	100c	100c



**Figure 1. Wart symptoms in 0.025, 0.05 and 0.1 g/L Famoxadone + Cymoxanil applied soils**

peroxychloride, Famoxadone + Cymoxanil, Mandipropamid + Mancozeb and Zoxamide + Mancozeb were evaluated in two infested field condition. The effects of fungicides on wart development rate in field 1 (87 sporangia/g soil) were given in Table 3. The disease was inhibited totally by Famoxadone + Cymoxanil.

Tolclophos Methyl + Thiram application was



**Figure 2. Wart symptoms in control vials**



**Figure 3. Inhibition of wart development in 0.2 g/L Famoxadone + Cymoxanil applied soil**

followed by Mandipropamid + Mancozeb with %93.92 effect Dimethomorph + Copperoxychloride with %93.73 effect and Zoxamide + Mancozeb with %92.29 effect respectively (Table 3). All the fungicides tested, decreased the disease severities and the differences between the inhibition rates of the fungicides were not statistically significant ( $P \geq 0.05$ ). In Famoxadone + Cymoxanil applied plots any wart symptom observed on potato plants. Despite their total inhibition effects in laboratory trials, some fungicides could not inhibit totally the wart development in some plots but the disease severities were significantly less than the control ( $P \geq 0.05$ ).



**Figure 4. Tubers with any wart in Famoxadone + Cymoxanil applied plots**

### 3. Effects of fungicides on total tuber numbers, diseased tuber rates and disease rates and percent effects of fungicides in field 1

Fungicides	Total tuber number	Diseased tuber number	Disease rate (%)	Effect(%)
Tolclophos Methyl + Thiram 30 + 30%	71	1	1.41	96.58
	43	0	0	100
	54	0	0	100
	56	0	0	100
	<b>56±5.6b</b>	<b>0.25±0.25b</b>	<b>0.35±0.35b</b>	<b>99.15±0.86a</b>
Dimethomorph + Copperoxychloride 6 + 40WP	33	1	3.03	87.88
	32	0	0	100
	47	0	0	100
	97	5	5.15	87.13
	<b>52.25±15.3b</b>	<b>1.50±1.19b</b>	<b>2.05±1.26b</b>	<b>93.75±3.61a</b>
Famoxadone + Cymoxanil 22.5 + 30%	49	0	0	100
	35	0	0	100
	60	0	0	100
	101	0	0	100
	<b>61.25±14.2b</b>	<b>0±0b</b>	<b>0±0b</b>	<b>100±0a</b>
Mandipropamid + Mancozeb 5 + 60%	108	3	2.77	93.29
	136	5	3.68	85.28
	166	2	1.20	97.12
	145	0	0	100
	<b>138.5±12.02a</b>	<b>2.50±1.04b</b>	<b>1.91±0.82b</b>	<b>93.92±3.19a</b>
Zoxamide + Mancozeb 8.3 + 66.7%	92	0	0	100
	125	0	0	100
	83	3	3.61	91.34
	124	11	8.87	77.83
	<b>106±10.84a</b>	<b>3.50±2.6b</b>	<b>3.12±2.1b</b>	<b>92.29±5.24a</b>
Control	63	26	41.27	—
	60	15	25	—
	72	30	41.67	—
	<b>55</b>	<b>22</b>	<b>40</b>	<b>—</b>
	<b>62.5±3.57b</b>	<b>23.25±3.2a</b>	<b>36.99±4.01a</b>	<b>—</b>

Tolclophos Methyl + Thiram application followed Famoxadone + Cymoxanil with %99.15 inhibition effect (Figure 5).



**Figure 5** The single tuber with a wart symptom in Tolclophos Methyl + Thiram applied plots

2nd and 3rd plots were %2.77, %3.68 and %1.20 respectively. There was no disease symptom in 4th plot Consequently the mean disease rate of Mandipropamid + Mancozeb was 1.91%.

Zoxamide + Mancozeb applied 3rd and 4th plots revealed 3.61 and 8.87% disease rates respectively, the mean disease rate was 3.12%. The number of diseased tubers, disease rates and percent effects of fungicides for field 1 were given Table 3. All the tested fungicides were decreased symptom development rates on tubers significantly ( $P \geq 0.05$ ). Differences between the disease rates and percent effects of tested fungicides were insignificant ( $P \geq 0.05$ ).

The number of diseased tubers, disease rates and percent effects of fungicides for field 2 were given Table 4. The second field contained 65 sporangium/g soil inocula and trial was conducted with the same fungicides and application rates. The same as field 1, any diseased tuber was found in Famoxadone + Cymoxanil applied plots, the effect of the fungicide was 100%. With the respect of inhibition effects, the fungicide was followed by Tolclophos methyl + Thiram with 97.31%, Dimethomorph + Copperoxychloride with 91.28%, and Mandipropamid + Mancozeb with 90.19% inhibition rate respectively. Zoxamide + Mancozeb exhibited the least effect (88.05%) (Table 4). Any significant difference was found between the effectiveness of all these fungicides ( $P \geq 0.05$ ).

The mean disease rate of control plots was 32.51%. The disease rates of Famoxadone + Cymoxanil applied plots were 0%. In Tolclophos methyl + Thiram applied plots, only 3rd plot exhibited 2.63% diseased tubers

In one of Tolclophos Methyl + Thiram applied plots, 1.41% disease rate was observed, any symptom was found in other plots. Consequently mean disease rate was calculated %0.35 for Tolclophos Methyl + Thiram. In Dimethomorph + Copperoxychloride applied plot 1 and Plot 2, disease rates were 3.03% and 5.15% respectively. There was no disease symptoms in the other plots. Consequently the mean disease rate of Dimethomorph + Copperoxychloride applications was 2.05%. In Mandipropamid + Mancozeb applications, disease rates of 1st,

**4. Effects of fungicides on total tuber numbers, diseased tuber rates and disease rates and percent effects of fungicides in field 2**

Fungicides	Total tuber number	Diseased tuber number	Disease rate (%)	Effect(%)
Tolclophos Methyl + Thiram 30 + 30%	70	0	0	100
	37	0	0	100
	38	1	2.63	89.25
	53	0	0	100
	<b>49.50±7.75bc</b>	<b>0.25±0.25b</b>	<b>0.66±0.66b</b>	<b>97.31± 2.69a</b>
Dimethomorph + Copperoxychloride 6 + 40WP	43	0	0	100
	22	1	4.55	88.04
	35	0	0	100
	27	2	7.40	77.06
	<b>31.75±4.61c</b>	<b>0.75±0.48b</b>	<b>2.99±1.82b</b>	<b>91.28±5.51 a</b>
Famoxadone + Cymoxanil 22.5 + 30%	64	0	0	100
	57	0	0	100
	67	0	0	100
	78	0	0	100
	<b>66.50±4.37ab</b>	<b>0±0b</b>	<b>0±0b</b>	<b>100 a±0a</b>
Mandipropamid + Mancozeb 5 + 60%	58	3	5.17	85.35
	79	2	2.53	93.35
	114	5	4.39	82.06
	92	0	0	100
	<b>85.75±11.74a</b>	<b>2.50±1.04b</b>	<b>3.02±1.15b</b>	<b>90.19a±4.04a</b>
Zoxamide + Mancozeb 8.3 + 66.7%	52	0	0	100
	46	3	6.52	82.86
	80	6	7.5	69.35
	60	0	0	100
	<b>59.50±7.41bc</b>	<b>2.25±1.44b</b>	<b>3.51±2.03b</b>	<b>88.05a±7.43a</b>
Control	85	30	35.29	—
	71	27	38.03	—
	94	23	24.47	—
	<b>93</b>	30	32.26	—
	85.75±5.31a	<b>27.50±1.66a</b>	<b>32.51±2.93a</b>	—

and mean disease rate was 0.66%. Dimethomorph + Copperoxychloride applied 2nd and 4th plots exhibited 4.55% and 7.40% disease rates respectively and the mean disease rate was 2.99%.

Mandipropamid + Mancozeb applied 1st, 2nd and 3rd plots showed 5.17%, 2.53% and 4.39% disease rates respectively and mean disease was 3.02%. Zoxamide + Mancozeb applied 2nd and 3rd plots exhibited 6.52% and 7.5% disease rates respectively and the mean disease rate was 3.51%. All fungicides decreased the disease rates significantly and the differences between the the rates were statistically insignificant ( $P \geq 0,05$ ).

As a result, effectiveness of the fungicides were almost similar in two different field trials. Potato wart disease caused by *S. endobioticum* has been the most important limiting agent of potato production since it had been detected on potatoes in early 1900's. It is one of four plant disease that subjected European Union's directory on it. EU has been apply the 69/464/EEC, EU 2022 council directory in order to control and prevent spread out of the disease.

Despite these precautions, the disease agent contaminated new potato fields of 39 countries. Because of this, cultural, chemical and biological control methods must be used additionally to the quarantine cautions.

The fact that growing resistant cultivars in the safety zone around infsted area is an useful application. Additionally to quarantine, long crop rotation, obligatory rules and only usage of resistant varieties have been adviced (Hampson 1993).

According to Hampson (1977), potato wart disease agent *S. endobioticum* has high resistance to fungicides. Many researchers indicated that the most sensitive period of the fungus is the time moving free zoospores to sensitive plant tissues. Additionally the researchers stated that, fungicides, applied to tuber surfaces, can not control the disease for a long time. Because of this, in this study it is aimed to inhibit the inoculum of the pathogen in the soil by means of soil treatment of some fungicides and prevent the infections of the sporangia to the potato sprouts.

Famoxadone + Cymoxanil, Tolclophos methyl + Thiram, Dimethomorph + Copperoxychloride, Mandipropamid + Mancozeb and Zoxamide + Mancozeb were found effective against to disease development in laboratory conditions. These fungicides were also tested in field trials. In the trials, fungicides were applied to the soil surrounding the potato tubers. The application concentrations of the fungicides were the high dosages in the laboratory tests which their registered usage concentrations of the fungicides against to zoosporial fungal diseases of vegetable and potatoes. In laboratory tests, the fungicides inhibited the pathogen by use of all concentrations (low and high). Because the soil environment is very wide, the use of the high concentration was preferred.

As a result, it is found that, all the fungicides decreased the disease

rates significantly in comparison with control plants. But, Famoxadone + Cymoxanil was the most effective fungicide, it exhibited 100% effect. This result is very important, because the disease is a disease with zero tolerance and caused by a quarantine pathogen. An effective fungicide applications can shorten approximate 30 years lifetime of the pathogen in soil. Nevertheless fungicide application techniques, application times and dosages needs detailed examinations. Because usage of chemicals has negative effects to natural environment and human health.

#### **Effectiveness of Famoxadone + Cymoxanil in Concentration 1**

The wart disease symptoms were observed 0.025, 0.05 and 0.1 g/l concentrations of Famoxadone + Cymoxanil (Fig 1). All control tubers produced wart symptoms. Famoxadone + Cymoxanil totally inhibited wart development at 0.2 g/L concentration (Fig 3). Consequently the effect was 100% at this concentration.

### **CONCLUSION**

As a result of the laboratory experiments, All the fungicides have inhibitory effects, but Propamocarb hydrochloride, Metalaxyl-M + Fludioxonil, Hymexazole could not prevent the wart development totally. Famoxadone + Cymoxanil, Tolclophos methyl + Thiram, Dimethomorph + Copperoxychloride, Mandipropamid + Mancozeb and Zoxamide + Mancozeb were found highly effective and the fungicides inhibited wart development totally. Consequently these fungicides were selected for field experiments.

Field experiments were conducted in two naturally infected areas in Derinkuyu district of Nevşehir. In control plots, the rates of infeced potato tubers were 36.99% in field 1 and 32.51% in field 2. In field 1, infection rates were 3.12%, 2.05%, 1.91% and 0.35% in Zoxamide + Mancozeb, Dimethomorph + Copperoxychloride, Mandipropamid + Mancozeb and Tolclophos methyl + Thiram applied plots respectively. The infection rate was 0% in Famoxadone + Cymoxanil applied plots. Another interesting result is that tuber numbers are significantly high in Mandipropamid + Mancozeb (138.75) and Zoxamide + Mancozeb (106) than the control plots (62.5) and the plots treated with other fungicides.

In field 2, infection rates were 3.51%, 3.02%, 2.99% and 0.66% in Zoxamide + Mancozeb, Mandipropamid + Mancozeb, Dimethomorph + Copperoxychloride and Tolclophos methyl + Thiram applied plots respectively. The infection rate was 0% in Famoxadone + Cymoxanil applied plots. In field 2, the highest tuber numbers were in Mandipropamid + Mancozeb (85.75) applied plots and control plots (85.75). But the tuber numbers in Zoxamide + Mancozeb (59.5) and Famoxadone + Cymoxanil (66.50) applied plots were statistically insignificant from Mandipropamid + Mancozeb applied plots and control plots. In respect of the efficiency of the fungicides, the results were parallel in two fields. Famoxadone + Cymoxanil

inhibited the wart development totally in both field trials. The fungicide use for the potato wart disease control by means of soil treatment may cause high costs and environmental problems. The fungicide is used for the potato mildew (*Phytophthora infestans*) widely. Fungicide applications are made by high volume applications and especially via springle irrigation system. Consequently a significant amount of fungicides deposit into the soil. The use of fungicides effective to wart disease, for the control of other potato diseases, in the safety areas may be useful and favourable for the integrated pest management strategies.

## REFERENCES

- Brooks, J.L., Given, J.B., Baniecki, J.F., Young, R.J., 1974. Eradication of potato wart in West Virginia. *Plant Disease Reporter* 58(4), 291-292.
- EU 1969. Council Directive 69/464/EEC on the control of Potato Wart. *Official Journal of the European Communities* L323/1, 561-562.
- EU 2022. Commission Implementing Regulation (EU) 2022/1195 of 11 July 2022 establishing measures to eradicate and prevent the spread of *Synchytrium endobioticum* (Schilbersky) Percival. *Official Journal of the European Union*, L 185/65, 12.7.2022.
- EPPO 2003. Phytosanitary procedures PM 3/59 (3) *Synchytrium endobioticum*: descheduling of previously infested plots. *Bulletin OEPP/EPPO Bulletin* (2017) 47 (3), 366-368. ISSN 0250-8052. DOI: 10.1111/epp.12409
- EPPO 2004. EPPO Standards, Diagnostic protocols for regulated pests, PM 7/28. *EPPO Bulletin* 34, 155-157.
- Ericson, J., 1914. Wart disease of potatoes. *Journal of the Board of Agriculture* 21, 135-136.
- Hampson MC. 1977. Screening systemic fungicides for potato wart disease. *Canadian Plant Disease Survey*, Volume 57: 75-78.
- Hampson, M.C. and Thomson, P.R. 1977. A quantitative method to examine large numbers of soil samples for *Synchytrium endobioticum*, the cause of potato wart disease. *Plant and Soil* 46, 659-664.
- Hampson, M.C., 1985. Pathogenesis of *Synchytrium endobioticum*. *Plant and Soil* 87, 241-250
- Hampson, M.C., 1988. Control of potato wart disease through the application of chemical soil treatments: a historical review of early studies (1909-1928). *EPPO Bulletin* 18, 153-161.
- Hampson, M.C. 1993. History, biology and control of potato wart disease in Canada. *Canadian Journal of Plant Pathology*, 15(4); 223-244.
- Hunt, H.R., O'Donnell, F.G and Marshall, R.P., 1925. Steam and chemical soil disinfection with special reference to potato wart. *Journal of Agriculture Research* 31, 301-363.
- Roach W.A., Glynn, M.D., Brierley, W.B. and Crowther, E.M., 1925. Experi-

ments on the control of wart disease of potatoes by soil treatment with particular reference to the use of sulphur. *Annals of Applied Biology* 12, 152-190.

Smith, I.M., MCnamara, D.G., Scott, P.R. and Holderss, M. 1997. *Quarantine Pests for Europe*. Second Edition. Data sheets on quarantine pests for the European Union and for the European and Mediterranean Plant Protection Organization. 925-929p. CAB Internationall, 1425.

**<sup>1</sup>Чакір Е., <sup>2</sup>Демірчі Ф.**

<sup>1</sup>Директорат захисту рослин Центрального Дослідницького Інституту імені Гайрету Міхалессі, Бульвар Фатіха Султан Мехмета, №66, 06172, Єнімахаль, Анкара, Туреччина

<sup>2</sup>Університет Анкари, Факультет аграрних наук, Кафедра захисту рослин, Університетський бульвар, №37/9; Гурмдушері 60, Кампусь Ель, ім. Гурмдушері Махалессі, 061356, Кешьорен, Анкара, Туреччина  
e-mail: <sup>1</sup>cakir@hotmail.com, <sup>2</sup>fdemirci@agri.ankara.edu.tr

**Захист картоплі від збудника раку (*Synchytrium endobioticum*) за допомогою фунгіцидних обробок ґрунту**

*Synchytrium endobioticum* є збудником раку картоплі і може знаходитись в ґрунті протягом кількох років завдяки спорангіям. Ефективний захист від цієї хвороби включає встановлення карантину та використання стійких проти хвороби сортів картоплі. До цього часу хворобу не вдалося викоринити. Метою дослідження було визначити ефективність фунгіцидів для обробки ґрунту у захисті від наростів раку картоплі. Досліди проводили з: пропамокарб гідрохлоридом 722 (КС)-концентрат-суспензія г/л; металаксиллом М + флудиоксонілом (10 + 25 г/л); гімексазолем (360 г/л); толклофосом метил + тирам (30 + 30%); диметоморфом + купероксихлоридом 6 + 40ВР — водорозчинні; фамоксадоном + цимоксанілом 22,5 + 30%; мандипропамід + манкоцеб (5 + 60%); зоксамід + манкоцеб (8,3 + 66,7%). Досліди в умовах ростової камери та у польових умовах показали, що фамоксадон + цимоксаніл (22,5+30%) здатний захищати від хвороби на 100% в обох умовах досліду.

**рак картоплі *Synchytrium endobioticum*; фунгіциди; контроль; обробка ґрунту**

Надійшла до редакції: 05.09.2023. Прийнята до друку: 09.09.2023

Надруковано: грудень, 2023

Опубліковано онлайн: лютий, 2024