Danish Research Service for Soil and Plant Sciences
State Plant Pathology Institute (H. Ingv. Petersen)
Pesticide department (E. Nøddegaard)
Botany department (A. Jensen)

1328. beretning

Control of potato wart disease (*Synchytrium endobioticum*) through methyl bromide soil disinfection

Bekæmpelse af kartoffelbrok (Synchytrium endobioticum) ved jorddesinfektion med methylbromid

A. Nøhr Rasmussen and H. Mygind

Summary

Since the first infested localities were found in 1923, the control of wart disease in Denmark has been indirect, the fungus being »starved« during a 12-years period, as for such period the growing of potatoes in infested areas is forbidden. In a safety zone around the locality, only varieties immune against wart disease may be grown.

Wart disease is under the control of the Danish Government Plant Protection Service. According to an EEC directive, the restrictions can only be abolished when, on the basis of an investigation carried through by the Plant Protection Service, wart disease is no longer found in the area.

Direct chemical control of this disease had proved impossible under Danish conditions until, in 1972, the first experiments with methyl bromide soil disinfection were started.

At the State Institute of Plant Pathology, Lyngby, 4 experiments were carried through in the 1972 to 75 period with a view to controlling wart disease in naturally infested areas. The object of the experiments was to investigate the possibility of effectively controlling the fungus by means of soil disinfection with methyl bromide, partly to take immidiate measures to control new attacks, and partly to eradicate the fungus in areas already infested with wart disease.

The treatments carried out according to the »hot gas« method, or according to the »Terabol« method, were applied in May at soil temperatures of 10° to 17°C measured at a depth of 15 cm.

In parallel with these experiments, check cultivations were made with soil samples in plastic buckets, the samples having been taken from the individual plots before and after treatment.

The experiments showed that it was possible to obtain effective control of the wart fungus with an application of 50 to 200 g methyl bromide 98 p.c. per m^2 for 72 hours. At lifting all parts of the plants were carefully examined and no pieces of wart tumour were observed in plants from the experimental plots or in those from the plastic buckets except in one locality (1972). However, the experiments also showed the importance of proper soil conditions at the time of treatment. The soil must be well prepared: porous and rather finely structured (*Peachey* and *Chapman* 1966). Soil moisture must be approximately 70 per cent of field capacity, and the soil temperature must not be below 10°C. However, numerous experiments for controlling other soil-borne fungi have shown that the fungicidal effect of methyl bromide increases with increasing temperature.

Key words: *Potato wart disease, methyl bromide.*

Resumé

Ved Statens plantepatologiske Forsøg, Lyngby, er der i årene 1972–75 gennemført 4 forsøg med bekæmpelse af kartoffelbrok på naturligt inficerede arealer. Formålet har været at undersøge, om det ved jorddesinfektion med methylbromid er muligt at opnå en effektiv bekæmpelse af svampen, dels for straks at kunne bekæmpe nye angreb, dels for at kunne udrydde svampen på allerede eksisterende brokarealer.

Behandlingerne, som er udført, dels efter »varmgas« metoden, dels efter »Terabol« metoden, er foretaget i maj måned ved jordtemperaturer på 10–17°C, målt i 15 cm's dybde.

I tilknytning til forsøgene er der udført dyrkningsforsøg i plasticspande i jordprøver udtaget før og efter behandlingen i de enkelte parceller.

Forsøgene viste, at det ved anvendelse af 50–200 g methylbromid 98 pct. pr. m^2 og en indvirkningstid på 3 døgn var muligt at opnå en effektiv bekæmpelse af kartoffelbroksvampen. Der blev ved optagning af planterne og nøje undersøgelse af alle plantedele ikke fundet broksvulster, hverken på planterne i parcellerne eller i plasticspandene undtagen i ét forsøg (1972). Forsøgene viste imidlertid også, at det er vigtigt, at de rigtige betingelser er til stede i jorden ved behandlingen. Jorden skal være porøs og have en fin struktur (*Peachey* og *Chapman* 1966) og have en fugtighed på ca. 70 procent af naturlig vandkapacitet samt en jordtemperatur på minimum 10°C. Mange forsøg med bekæmpelse af andre jordboende svampe har dog vist, at methylbromid's fungicide virkning øges med stigende temperatur.

Nøgleord: *Kartoffelbrok, methylbromid.*

Introduction

Potato wart disease *(Synchytrium endobioticum)* is a dangerous plant disease from an international point of view.

Since its first appearance in this country in 1923 registration of new localities infested with wart disease has come under public control. Such control is exercised by the Government Plant Protection Service, Hellerup, in pursuance of the Order on the Control of Wart Disease issued by the Ministry of Agriculture on the basis of The Control of Dangerous Plant Diseases and Pests Act.

The Latest Order, dated December 12, 1974, has been worked out in accordance with the EEC Council Directive No. 69/464/EEC of December 8, 1969, concerning Control of Wart Disease in Potatoes.

Directives to growers

There is a prohibition of growing potatoes in areas where attacks of wart disease have been observed. Further, in a defined safety zone only potatoes resistant to wart disease may be grown. The Plant Protection Service publishes every year a list of those varieties which are immune to wart disease.

In addition, plants for further cultivation must not be grown in the infested areas or in areas in the safety zone and it is forbidden to remove other plants and parts of plants with adherent soil.

According to the regulations in force prior to the 1974 Order mentioned above, the Plant Protection Service would cancel the restrictions after a period of 12 years.

However, according to the new regulations contained in the said Order, it has been laid down that, in accordance with the EEC Directive, a cancellation of the restrictions can only take place, when an investigation made by the Plant Protection Service has proved, that wart disease can no longer be found in the area in question.

Indirect Control

The control of wart disease in potatoes has proved very difficult during the period of more than 50 years in which the disease has existed in this country. In fact, the only control measure applicable was an indirect one, namely, that of »star-

ving« the fungus for a considerable number of years by forbidding, as mentioned above, the growing of potatoes in the area infested with wart disease, i.e. usually vegetable gardens. Wart disease has very rarely been found in farm land in Denmark. However, if the growing of potato varieties susceptible to wart disease continues, which had been the case up to the time of the »official« observation of an attack, *resting sporangia* of the fungus will accumulate in the soil thereby highly increasing the infection potential.

The persistance and viability of the resting sporangia are unusually long and may be expected to exist for a great number of years. Under Danish conditions, such a period is estimated to be a minimum of 12 years in cultivated soil.

From other countries, the said number of years has been reported to be considerably longer, especially in soils that have not been cultivated for a long time.

Direct control

A desire has been felt for many years that direct chemical control might make it possible to cancel the restrictions imposed on wart disease infestation, with immidiate effect as soon as a treated area is found to be free of such infestation.

However, under European conditions, there has been no effective and reliable method of controlling wart disease in potatoes. Attemps have previously been made to disinfect the soil by applying various chemicals; however, among such preparations only raw benzene and formalin have proved to be sufficiently effective (*Eriksson* and *Hammarlund* 1915; *Lemmerzahl* 1937).

In Pennsylvania, USA (*Hartmann* 1951 and 1955), an eradication plan was made by which it should be possible to control wart disease infestation in the 1113 localities infested at that time. The preparations used were ammonium-thio-cyanate, copper sulphate or 40 p.c. formalin in a 5 p.c. solution. However, it involved the use of large amounts of poisonous substance measured in kilogrammes or litres of liquid per 100 m² and that such soil disinfection measures would probably not be acceptable under European conditions, on account of the destruction of micro-organisms in the soil, and the danger of sub-soil water pollution.

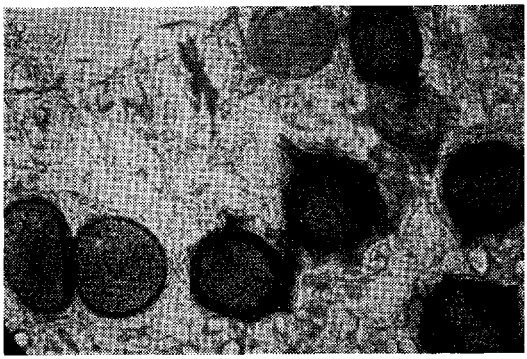

Fig. 1. Sporangia of potato wart in tumour tissue; right: 4 thickwalled resting sporangia.
Photo: Olaf Nielsen

It must also be mentioned that in West Virginia (*Brooks* et al. 1974) formalin was similarly used for small areas, and copper sulphate for larger areas. The areas treated were declared free of wart disease infestation when no attacks were observed on the plants in three consecutive potato crops.

In Canada (*Monro* et al. 1970) methyl bromide and ethylene oxide have been used for soil disinfection but, so far, in laboratory experiments only.

Control experiments with methyl bromide

After 1971, when it was permitted to use preparations containing 98 p.c. methyl bromide for soil disinfection in Denmark, a series of experiments and investigations were carried through in 1972 to 75 at the State Plant Pathology Institute at Lyngby with a view to finding an effective method for controlling wart disease by means of methyl bromide soil disinfection.

Procedure

In 1972 and 1973, experiments were carried out in areas which, for a number of years, had been used for the production of infectious material for the purpose of testing new varieties for potato wart.

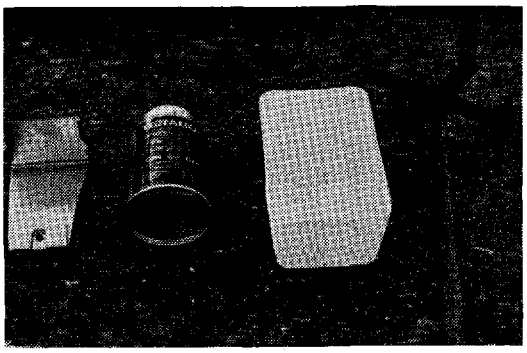

Fig. 2. Individual parts for Terabol treatment; from left to right: can holder with perforating pin; can containing 500 g methyl bromide; evaporation pan and stand.
Photo: Arne Jensen

In 1974 and 1975 the Government Plant Protection Service pointed out some infested areas in private gardens, and the most suitable areas were found by trial cultivation of a susceptible potato variety in samples of soil buckets.

In 1972, methyl bromide was applied by the hot gas method and, in 1973 to 75, using the Terabol method.

When the hot gas method is used, methyl bromide is heated up to 90°C in a special vaporizer from where the hot bromide gas is led through a pipe in under the polyethylene sheets covering the area to be disinfected, and the distribution of the gas is done by means of perforated lay-flat plastic tubes. When the Terabol method is used, the methyl bromide is distributed in cans of 500 g each, which are placed in evaporating bowls in holders on stands about 10 cm above the ground-level. After covering them with polyethylene sheets, the cans are perforated by means of an opener attached to the holder causing the methyl bromide to pour out into the evaporating bowls from where the evaporation takes place (figure 2).

At the time of the experiments, the soil was porous with a good structure and a suitable degree of moisture, except for 1972 when it was too dry and lumpy. The applications were made in May at soil temperatures of 10° to 17°C measured at a depth of 15 cm and with an active period of 72 hours. The net size of the plots varied from 5 to 10 m^2, with 2 replications. Approximately 2 weeks after the treatment, 10 tubers per m^2 of the highly susceptible variety Alma were planted. The plants were lifted at flowering, and all parts were carefully inspected for wart tumours. Table 1a shows the experimental data and table 1b the soil texture of the experimental fields.

In parallel with these experiments, check-cultivations were done in plastic buckets with soil samples from the experimental plots. The purpose was, first to select the best suited areas for

Table 1a. *Data from the control experiments against wart disease with application of methyl bromide 98 per cent*

Year	*Dosage g/m²*	*Net size of plots m²*	*Dates of appli-cation*	*Duration of treatm. hours*	*Soil temp. °C*	*Dates of plant-ing*	*lift-ing*
1972	75; 125	10.0	May 24	72	15	–	–
1973	50; 75; 150	5.0	May 30	72	17	June 13	Aug. 22
1974	50; 100; 200	10.0	May 21	72	15	June 4	Sept. 2
1975	50; 100; 200	10.0	May 13	72	10	May 27	Sept. 8

Table 1b. *Soil texture of the experiment fields in per cent*

Locality/year		*Clay*	*Silt*	*Fine sand*	*Coarse sand*	*Humic*
Stensved	1972	11.6	17.3	45.6	29.2	2.3
Lyngby	1973	6.5	12.6	40.9	35.7	4.3
Langelund	1974	3.3	2.5	18.5	73.6	2.1
Snedsted	1975	8.6	9.8	34.4	44.2	3.0

experiments already indicated by the Government Plant Protection Service; and second to determine the degree of infestation of the individual plots before treatment; finally, to be able to check the effectiveness of the control measures by taking soil samples after treatment, before potatoes are planted in the area.

One soil sample of 20 litres was taken from each plot by means of a soil auger taking 250 cm^3 of soil per bore to a depth of 20 cm. Potatoes were grown in these soil samples in early June. Each soil sample was divided into 6, and transferred to 8-litres buckets, already filled to 1/3 of their capacity with gravel. (As the wart disease fungus does not attack the roots, this procedure permitted the use of less soil).

Seven tubers of the highly susceptible variety Alma were planted in each bucket. All sprouts more than 3 mm long had been removed, by advance, from the tubers, which were planted with the sprout end upwards, the tubers being partly pressed down into the gravel. Then the soil from the samples was tipped into the bucket to about 2 cm from the edge. The buckets were placed in sphagnum moss in a frame under a shading net in order to keep temperature and moisture at a suitable level for the fungus. In hot and sunny weather frequent watering with spray-nozzles was necessary to keep down the temperature.

The first careful watering with a can took place 3 to 4 days after the planting, when the sprouts were 2 to 3 mm long. In the first week after inoculation an 0.05 p.c. solution of calcium nitrate was used for watering; *Esmarch* (1927) has shown that $Ca(NO_3)_2$ has a stimulating effect on the »hatching« of the resting sporangia.

Results

The results optained are shown in table 2. Six different dosages were used, but not in all experiments. Where the table shows no entry, the dosage in question has not been tested. The columns »before/after treatment« refer to the results from cultivation in soil from samples taken before and after treatment, respectively, prior to the planting of potatoes in the area. The figures designate grammes per bucket. The column »at time of lifting« refers to the experimental area, and the figures designate grammes per plot. In 1972, no potatoes were planted in the treated area; only samples of the soil for »check-growing« in buckets were taken before and after treatment. In 1973, when it was possible to use an untreated plot for control, no soil samples were taken after treatment. The plants in the untreated plots were, however, severely attacked by potato nematodes *(Heterodera rostochiensis)* and were, therefore, small at the time of lifting – one of the reasons for abandoning the experimental area.

The figures show that, in 1972 when the trial conditions were unfavourable because of the dry and lumpy soil, the control measures had not been sufficiently effective. In the other experiments where the soil was in a proper condition, no new wart tumours were observed after treatment, neither in the case of potatoes growing in the soil

Table 2. *Weight in grammes of wart tumours at the time of lifting*

Grammes methyl bromide 98 p.c.per m^2	*1972*		*1973*		*1974*			*1975*		
	treatment		*before treatment*	*at time of lifting*	*treatment*		*at time of lifting*	*treatment*		*at time of lifting*
	before	*after*			*before*	*after*		*before*	*after*	
0	–	–	30.3	170	–	–	–	–	–	–
50	–	–	65.5	0	203	0	0	4.5	0	0
75	340	4.5	26.5	0	–	–	–	–	–	–
100	–	–	–	–	297	0	0	19.0	0	0
125	313	4.0	–	–	–	–	–	–	–	–
150	–	–	31.0	0	–	–	–	–	–	–
200	–	–	–	–	286	0	0	51.5	0	0

Fig. 3. Experimental plots after removal of plast foil, here just above the surface to indicate the boundaries of the plot.

Photo: A. Nøhr Rasmussen

samples taken, nor in the treated plots of the experimental area.

Discussion and Conclusion

The experiments were done in naturally infested areas to investigate the possibility of obtaining effective control of the wart disease fungus by means of methyl bromide disinfection of the soil.

The results show that it is possible to obtain 100 per cent control of the fungus by application of 50 to 200 g methyl bromide 98 p.c. per m^2. Further, the experiments indicated the importance of the right soil conditions. In 1972 when the soil conditions were not suitable due to local climatic conditions the effect was not satisfactory, even after the application of 125 g/m^2.

As it may be difficult in practice to secure the same favourable conditions in the soil as those for the above-mentioned experiments, an increased dosage to 100 g per m^2 may be able to secure the desired effect although such increase alone will never improve the ideal conditions.

For proper soil conditions the soil must be porous, have a fine structure, and have a moisture content of approximately 70 per cent of field capacity. The soil temperature should be at least 10°C measured at a depth of 15 cm, but as many of the control experiments against other soil borne fungi have shown that the fungicidal effect of methyl bromide is increased with increasing temperatures, 12° to 15°C must be considered as having a more reliable effect.

Literature

Assche, van, C., 1971: Behaviour and perspectives of chemical soil fumigation. Proc. 6th Br. Insectic.Fungic. Conf. Brighton, 3, 706–710.

Bekendtgørelse om bekæmpelse af kartoffelbrok. Landbrugsministeriets bekendtgørelse nr. 600 af 12. december 1974.

Bekendtgørelse om indførsel af planter m.m. Landbrugsministeriets bekendtgørelse nr. 302 af 6. august 1968, som ændret ved Landbrugsministeriets bekendtgørelse nr. 149 af 10. april 1970.

Dorozhkin, N.A., 1958: The biological basis of agronomic methods of control of the pathogen of potato wart Synchytrium endobioticum (Schilb.) Percival. The conference on potato wart disease. Smolenice. Lectures. Slovak Academy of Sciences.

Drosihn, U.G., 1967: Untersuchungen über die physikalische und chemische Verhalten von Methylbromid als Bodenentseuchungsmittel. Dissertation, Technischen Universität, Hannover, 53 s.

Drosihn, U.G., 1968: Untersuchungen über die Diffusion von Methylbromid bei der Bodenbegasung. Zeitschrift f. Pflanzenkrankheiten und Pflanzenschutz 75, 665–673.

Drosihn, U.G., Stephan, B.R. und *Hoffmann, G.M.*, 1969: Untersuchungen über die Bodenentseuchung mit Methylbromid. Zeitschrift f. Pflanzenkrankheiten und Pflanzenschutz 75, 272–287.

Esmarch, F. (1927): Untersuchungen zur Biologie des Kartoffelkrebses II. Ang.Bot. 9:88–124.

Gallay, D.J., Hague, N.G.M., 1967: Some factors affecting the efficacy of methyl bromide fumigations of glasshouse soils. Proc. 4th Br. Insectic. Fungic. Conf. Brighton (1) 56–62.

Hammarlund, C., 1915: Försök med utrotning av potatiskräfta. Medd. från Centralanstalten för försöksv. på jordbruksomr., nr. 127, pp 6.

Hartmann, R.E., 1947: Potato wart in Pensylvania. Proc. Penn. Acad. Sc. 17:71.

Hartmann, R.E., 1951: Potato wart in America. Pl. Dis. Rep. 35:268.

Hartmann, R.E., 1955: Potato wart eradication program in Pennsylvania. Amer. Potato Journ. 32: 317–326.

Hoffmann, G.M., Zinkernagel, V., 1972: Zur Abtötung von Dauerorganen pathogener Boden-

pilze durch Bodenentseuchung mit Terabol. Gartenwelt 72 (14), 291–293.

Holmberg, C., 1953: Potatiskräftåtgärderne i Sverige under 25 år. Växtskyddsnotiser 5–6: 90–93.

Malkomes, H.P., 1972: Der Einfluss von Bodenbegasungen mit Methylbromid (Terabol) auf gärtnerrische Kulturpflanzen. I. Bromidaufnahme und Bromidtoleranz bei Zierpflanzen. Zeitschrift f. Pflanzenkrankheiten und Pflanzenschutz 79 (5) 274–290.

Malkomes, H.P., 1972: Der Einfluss von Bodenbegasungen mit Methylbromid (Terabol) auf gärtnerrische Kulturpflanzen. II. Bromidaufnahme und Bromidtoleranz bei Gemüsepflanzen. Zeitschrift f. Pflanzenkrankheiten und Pflanzenschutz 79 (6): 321–338.

Monro, H.A.U., Olsen, O.A. & Buckland, C.T., 1970: Methyl-bromide and ethylene oxide fumigation of Synchytrium endobioticum. Can. J.Pl. Sci. 50 (6): 649–658.

Mygind, H. & Nøhr Rasmussen, A., 1976: Kartoffelbrok, levevis, forebyggelse og bekæmpelse. 1251. Meddelelse, Statens Forsøgsvirksomhed i Plantekultur. 78. årgang.

Neumann, H., 1939: Beobactungen über die Lebensdauer von Dauersporangien des Kartoffelkrebserregers (Synchytrium endobioticum) im bearbeiteten Felde. Zeitschrift f. Pflanzenkrankheiten und Pflanzenschutz 49: 93–94.

Olsen, O.A., 1964: Chemical control of wart in potatoes. Proc. C. Phytopath. Sec. 31: 23 pp.

Peachey, J.E. & Chapman, Margaret R, 1966: Chemical Control of Plant Nematodes. Techn. Com. No. 36, 119 pp. Commonwealth Agric. Bureaux, Farnham Royal, Bucks.

Reber, H., 1967 a: Vergleichende Untersuchungen zur Toxizität und Selektivität von Entseuchungsmitteln für Bodenmikroorganismen. Zeitschrift f. Pflanzenkrankheiten und Pflanzenschutz 74, 414–426.

Reber, H., 1967 b: Untersuchungen über die Wiederbesiedlung eines chemisch entseuchten Bodens. Zeitschrift f. Pflanzenkrankheiten und Pflanzenschutz 74, 427–438.

Zakopal, J., 1970: Neue Möglichkeiten zur Inaktivierung der Dauersporangien des Kartoffelkrebserregers Synchytrium endobioticum (Schilb.) Perc. Zentbl. Bakt. Parasitenkunde Abt. 2, 125 (5): 505–514. Inst. Pl. Prot., Prague, Czechoslovakia.

Manuscript received 23th September 1976