JOURNAL OF THE SCIENTIFIC AGRICULTURAL SOCIETY OF FINLAND
Maataloustieteellinen Aikakauskirja
Vol. 55: 431–450, 1983

Damping-off of sugar beet in Finland. II. Disease control

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Abstract. In pot and field experiments carried out in 1979–1981, the systemic funqicide hymexazol prevented satisfactorily soil borne damping-off of sugar beet caused mainly by the fungus *Pythium debaryanum* auct. non Hesse. The results with the combination hymexazol + thiram were still better. This treatment gave very good protection against the disease up to about two to three weeks after emergence, increased the yield on the average by 5–10 % and produced considerably thicker and denser stands. Thereafter a large number of beets may have become infected, but no great damage was caused as only few died. Band spraying at emergence using hymexazol with a large amount of water as well as spraying into the seed furrow prevented the outbreak of the disease almost completely. Liming had little effect on damping-off.

Introduction

In modern sugar beet cultivation, the method of sowing to stand has become common. According to DUNNING (1970), the fungicide treatment of sugar beet seed is commonly applied in most countries and cannot be dispensed with, because damping-off is considered one of the most significant diseases of beet. In Europe during 1968–1970, the greatest losses due to damping-off occurred in Poland, Romania, Czechoslovakia and Hungary. In Ireland, too, the disease was reported to be severe (DUNNING 1970). In 1979–1980, the main disease-causing factors at the seedling stage in 16 European countries were in the decreasing order of frequency: *Phoma* (13), *Pythium* (13), *Aphanomyces* (8), *Rhizoctonia* (6), *Fusarium* (3), *Alternaria* (2) (DUNNING & HEIJBROEK 1981).

In controlling the seed borne damping-off of sugar beet, seed dressing with mercurial compounds or thiram has been predominating (GATES & HULL 1954, GATES 1959, NÖLLE 1960, LÜDECKE & WINNER 1963, LINNASALMI 1970, MÖLLERSTRÖM 1974). However, maneb and mancozeb have also been reported to control damping-off (DARPOUX et al. 1966, KOCH 1979, HRUBESH & WIESER 1978). In recent years, seed treatment with iprodione, metalaxyl or hymexazol has proved effective against soil borne pathogens (DUNNING & HEIJBROEK 1981). As early as in 1952, HILLS and LEACH found certain soil-row spray treatments to be effective and superior to standard seed treatments. SCHULTZE and BOHLE (1976) also achieved promising results with this method using fenaminosulf as soil fungicide. VESELÝ (1978) has been able to control damping-off of sugar beet biologically using oospores of the fungus *Pythium oligandrum* Drechs. as seed dressor.

In Finland, the damping-off of sugar beet is firstly caused by the soil borne fungus *Pythium debaryanum* auct. non Hesse and secondly by different species of *Fusarium* (VESTBERG et al. 1982). The aim of this study was to find out the most effective ways of controlling damping-off of sugar beet by means of seed dressing, spraying or soil treatment and preventive control by liming. Some preliminary biological control experiments have also been carried out. The investigation were conducted during 1979–1981 with the co-operation of the Department of Plant Pathology, University of Helsinki, and the Finnish Sugar Beet Research Centre.

Pot experiments

Materials and methods

The following pot experiments were carried out to control damping-off: seed dressing, spraying treatments, application of fungicide to the seed furrow and surface soil, liming and biological control experiments. In the experiments, naturally contaminated soil from the sugar beet field at Viikki Experimental Farm was used. The sugar beet seed used was Monohill. Fungicide spraying was carried out with a hand spray either at emergence and/or at different intervals after emergence. The amounts of water used ranged from 0.1 to 1.5 l/m^2. In the liming experiments, hydrated fine ground lime was mixed into the pot soil. In one experiment hymexazol was mixed into the soil surface, about 5 cm deep.

All the pot experiments were carried out in a greenhouse at +18 – +20°C. Two experiments were carried out alongside at lower temperature, +8 – +10°C.

In the pot experiments, emergence was followd and healthy and diseased seedlings were counted at regular intervals after emergence until there were no symptoms of damping-off.

Results

In a premilinary experiment against damping-off, captafol proved the most effective at emergence, but at the end of the experiment propamocarb seed treatment gave the greatest number of healthy seedlings.

Seed treatment	Emergence %	Healthy plants at the end of the experiment %
Untreated	78	17
Captafol (5.0 g a.i./kg seed)	100	19
Metalaxyl (0.25 g)	99	22
Metalaxyl + thiram (0.25+4.0 g)	95	35
Propamocarb (18.8)	84	68
Thiram (4.0 g)	89	10

The seedlings were sprayed at emergence and at different stages thereafter, but no additional effect was observed.

In a pot experiment in 1980, propamocarb and hymexazol were used as seed dressors at two temperatures. The temperature clearly affected the extent of infection and the control result. At low temperatures, only moderate outbreads of damping-off occurred and all the seed dressors used proved very effective as compared with untreated plots. At high temperatures, there were severe outbreaks of damping-off and only hymexazol gave good results.

Seed treatment	Healthy plants at the end of the experiment %	
	+8°C	+18°C
Untreated	70	4
Hymexazol (10.5 g a.i./kg seed)	96	91
Hymexazol + tiophanat methyl (10.5+1.0 g)	95	76
Hymexazol + benomyl (10.5+1.0 g)	91	21
Methoxyethulmercury silicate (0.09)	80	2
Propamocarb (18.8 g)	96	5
Propamocarb + tiophanatmethyl (10.5+1.0 g)	95	76
Propamocarb + benomyl (10.5+1.0 g)	91	21
Thiram (4.0 g)	85	3

Hymexazol alone at high temperatures gave better results than hymexazol combined with tiophanatmethyl or benomyl. In 1980, a seed dressing and spraying experiment was carried out in a greenhouse at high and low temperatures. With regard to temperature, the results were similar to those in the seed dressing experiment of the same year reported above. Spraying at emergence did not improve results at low temperatures. At high temperatures, only hymexazol and hymexazol + tiophanatmethyl were effective, particularly when sprayed. Spraying at emergence with greater amounts of water gave better results.

Seed treatment	Spraying	Healthy plants at the end of the experiment %	
		+8°C	+18°C
Untreated	No spraying	44	9
Hymexazol (10.5 g a.i./kg seed)	No spraying	83	10
Hymexazol (10.5 g)	(1.05 g a.i./m², 0.3 l/m²)	86	55
Hymexazol (10.5 g)	(5.25 g, 1.5 l)	88	83
Hymexazol (10.5 g) + tiophanatmethyl (1.0 g)	No spraying	84	17
Hymexazol (10.5 g) + tiophanatmethyl (1.0 g)	(1.05+0.11 g, 0.3 l)	86	61
Hymexazol (10.5 g) + tiophanatmethyl (1.0 g)	(5.25+0.55 g, 1.5 l)	85	98
Propamocarb (18.8 g)	No spraying	90	7
Propamocarb (18.8 g)	(0.43 g, 0.3 l)	75	10
Propamocarb (18.8 g)	(2.15 g, 1.5 l)	90	6
Thiram	No spraying	89	8

In another pot experiment in 1980, variable amounts of hymexazol (1.4–14.0 g/kg seed) were tested using both seedling spraying and soil treatment (Table 1). Due to the fact that untreated seed emerged well (90 %), no difference was found with regard to emergence between the amounts used for seed dressing. At the end of the experiment, only 9 % of the untreated seedlings were healthy, and even seed dressing (3–14 % healthy seedlings) proved ineffective against damping-off in this experiment. Spraying especially with great amounts of water, proved somewhat effective, but the best results were obtained by mixing the fungicides into the soil. This treatment gave 75–92 % healthy seedlings (Table 1).

A hymexazol experiment in 1981 showed that only when the amount of seed disinfectant used rached 7.7 g/kg seed did not control result improve significantly (Table 2). In another experiment of the same year, hymexazol was applied to the seed furrow immediately before sowing (Table 3). The damping-off percentage was 70 % with untreated seed, but only 9 % when as little as 0.005 g/m² was applied to the seed furrow.

In greenhouse experiments, biological control of damping-off has been studied using oospores of the fungus *P. oligandrum* as seed dressing. In an experiment in 1980, there was 97 % damping-off in untreated plots, while in treatments with *P. oligandrum* the result was 70–99 %. There was a statistically significantly greater number of healthy seedlings only with the combination *P. oligandrum* + benomyl (Table 4). In a similar trial in 1981, there were no statistically significant differences in the health of the seedlings.

In the greenhouse liming experiment, the percentage of healthy seedlings rose from 29 to 59 % with pH rising from 5.2 to 6.6 (Table 5). The effect of liming on emergence was not equally significant: 3 and 6 g/l soil increased emergence, while 9 g/l soil decreased emergence. Liming was also discovered to improve the effect of fungicides (Table 5).

Table 1. The effect of seed and soil treatment on emergence and percentage of healthy sugar beet plants at the end of the experiment. Greenhouse experiment in 1980.

Treatment					Healthy plants at the end ot the experiment
Seed treatment		Soil treatment			
Fungicide	Dosage g a.i./kg seed	Type of application[1)]	Dosage g a.i./m²	Emergence %	%
Untreated	–	–	–	90	9
Hymexazol	1.4	–	–	92	3
"	1.4	a	1.05	88	5
"	1.4	b	5.25	88	18
"	1.4	c	2.00	96	77
"	4.2	–	–	95	7
"	4.2	a	1.05	89	6
"	4.2	b	5.25	92	26
"	4.2	c	2.00	89	75
"	8.4	–	–	93	14
"	8.4	a	1.05	93	44
"	8.4	b	5.25	98	55
"	8.4	c	2.00	93	83
"	14.0	–	–	94	6
"	14.0	a	1.05	96	5
"	14.0	b	5.25	98	18
"	14.0	c	2.00	96	92
Hymexazol + thirm	8.4 +4.0	–	–	90	11
" "	8.4 +4.0	a	1.05 + 0.48	97	9
" "	8.4 +4.0	b	5.25 + 2.40	97	29
" "	8.4 +4.0	c	hymexazol 2.00	91	80

1) a = Spraying at emergence, 0.3 l water/m², 0.35 % suspension
b = Spraying at emergence, 1.5 l water/m², 0.35 % suspension
c = Application of 4 % hymexazol powder 5 cm deep in the soil

	F-value	
	Emergence	Healthy plants at the end of the experiment
Seed treatment	1.10	10.62***
Soil treatment	–	177.95***
Seed treatment + soil treatment	–	2.64**

Table 2. The effect of seed treatment with hymexazol and thiram on emergence and percentage of healthy beet plants at the end of the experiment. Greenhouse experiment in 1981.

Seed treatment: Fungicide	Dosage g a.i./kg seed	Emergence %	Healthy plants at the end of the experiment %
Untreated	–	71	23
Hymexazol	8.4	88	63
Hymexazol + thiram	5.6+4.0	95	49
" "	7.7+4.0	95	87
" "	9.8+4.0	96	90
" "	11.9+4.0	95	95
" "	14.0+4.0	93	93
" "	16.1+4.0	96	95
" "	18.2+4.0	94	94
Thiram	4.0	91	41
F-value		1.14	27.08***
$LSD_{t0.05}$			12.00

Table 3. The effect of hymexazol seed furrow application on emergence and percentage of damping-off of sugar beet. Greenhouse experiment in 1981.

Seed furrow application g a.i./m^2	Emergence %	Damping-off %
–	69	70
0.005	82	9
0.01	84	6
0.02	88	2
0.04	90	1
0.08	93	2
0.12	91	1
F-value	11.10***	32.58***
$LSD_{t0.05}$	13	16

Table 4. The effect of seed treatment with oospores of *Pythium oligandrum* and some fungicides against damping-off of sugar beet. Pot experiment in 1980 and 1981.

Seed treatment		1980		1981	
	Dosage g a.i./kg seed	Emergence %	Damping-off %	Emergance %	Damping-off %
Untreated	–	96	97	76	45
Hymexazol	8.4	76	87		
" + thiram	8.4+4.0			93	28
Methoxyethylmercury silicate	0.09	86	94		
Pythium oligandrum – biopreparation (1980)	1.0	82	88		
" "	2.0	79	70		
" "	5.0	82	99		
" "	10.0	89	98		
" "	16.0			76	44
" "	20.0	88	96		
Pythium oligandrum 1980 + benomyl	1.0+1.0	87	91		
" "	2.0+1.0	61	78		
" "	5.0+1.0	90	97		
" "	10.0+1.0	87	100		
" "	20.0+1.0	69	53		
Pythium oligandrum (1981)	16.0			79	61
" " " + benomyl	16.0+1.0			76	39
F-value		3.20**	3.64**	2.27	1.98
$LSD_{t0.05}$		6.2	22.2		

Table 5. The effect of liming and seed treatment on emergence and percentage of healthy sugar beet plants at the and of the experiment. Greenhouse experiment in 1980.

Liming	pH
No lime application	5.2
Hydrated fine ground lime 3 g/l soil	6.1
" " " " 6 " "	6.5
" " " " 9 " "	6.6

Seed treatment	Dosage g a.i./kg seed	Liming: No lime, Emergence %	No lime, Healthy plants at the end of the experiment %	3 g/l soil, Emergence %	3 g/l soil, Healthy plants at the end of the experiment %	6 g/l soil, Emergence %	6 g/l soil, Healthy plants at the end of the experiment %	9 g/l soil, Emergence %	9 g/l soil, Healthy plants at the end of the experiment %
Untreated	–	83	29	83	47	88	56	79	59
Hymexazol	10.5	95	66	96	87	95	74	88	88
Methoxyethyl-mercury chloride	0.09	85	38	94	71	96	60	85	63
Propamocarb	18.8	89	46	96	63	95	67	91	78
Mean		88	45	92	67	94	64	86	72

	F-value: Emergence	F-value: Percentage of healthy plants at the end of the experiment
Liming	4.25**	25.82***
Seed treatment	5.13**	16.04***
Liming + seed treatment	0.36	0.79

Field experiments

Materials and methods

The locations of the field experiments were chosen on the basis of earlier experiments which showed the most severely infected fields owned by sugar beet farmers. Seed dressing tests and seed dressing + spraying tests were carried out yearly. Liming tests were conducted in 1980 and 1981. In 1981, the application of fungicide to the seed furrow was studied. In addition to chemical tests, biological fungicides were used in two experiments.

The Sugar Beet Research Centre was responsible for the practical arrangements related to the experiments during the growing season. Seed dressing was carried out at the Sugar Beet Research Centre as near to sowing time as possible. The seed used was naked Monohill. In an experiment in 1980, pelleted seed was used in one treatment, whereas in 1981 pelleted seed was used in all treatments.

Band spraying was done with a propane spray and a large amount of water. In 1979, 3000 l of water/net ha was used and the spraying band was about 10 cm, in 1980 and 1981, 2000 l/net ha and 5 cm, respectively. Hydrated fine ground lime was used to raise the pH level. In 1980, 3 and 6 tons/ha was spread onto the fields after sowing, whereas in the 1981 liming test it was spread before sowing and tilled in. In 1981, an attempt was made to raise the pH to 7.5. The amount needed to reach this level was called the "normal liming amount". Also 1.5 times this amount was used. In field experiments, *Pythium oligandrum* biopreparation and Eokomit compost preparation were used for biological control. Eokomit is a mixture of certain bacteria living in the soil, mostly *Azotobacter chroococcum* Beijerinck., *A. beijerinckii* Lipman, *Bacillus subtilis* and *B. stearothermophilus* Donk.

In 1979 and 1980, the experimental plots consisted of only 1 or 2 beet rows, 2×5 m, 2×16 m or 1×30 m, depending on the trial. In 1981, the plots consisted of 5 20-m rows, except for the plots in the liming test which were 10 m×10 m. All the experiments were inspected twice and the healthy and infected seedlings counted: the first time about 10 days after emergence with the seedlings at the cotyledon stage, the second time about 10–14 days later when the seedlings had 2–4 pairs of true leaves. In 1979, the number of seedlings along a length of 6 m per plot were counted, in 1980 along 10 m and in 1981 along 12 m per plot. In 1979, the yield was not examined after the damping-off stage, whereas in 1980–1981 the yield, number of beet roots per ha and sugar percentage were determined in the autumn. The samples were taken along a length of 15 m per plot in 1980 and 20 m per plot in 1981, but not the same place damping-off samples were taken from in the early summer.

Weather conditions 1979–1982

The mean mothly weather conditions over three years are shown in Table 6. In 1979, May and June, which are important months with regard to damping-off, exceeded normal temperatures. In 1980, May was rather cool and June very warm, in 1981 vice versa. On the whole the growing season during 1979–1980 was warmer than normally and in 1981 somewhat colder than normally.

In 1979, May and June were drier than normally, whereas in July, August and September rainfall was heavy. In 1980, July was rather dry, in August it rained heavily, whereas rainfall was normal during the other months. In 1981, rainfall was heavy in July and August, whereas June and September were relatively dry Table 6).

Table 6. Monthly mean temperature and rainfall during May – September 1979–1981 expressed as differences from "normal" (1931–1961) values. Averages from the following observation stations: Helsinki Kaisaniemi, Hattula Leteensuo, Turku Airport and Kokemäki Peipohja.

	Mean temperature °C				Rainfall, mm			
		Difference from normal				Difference from normal		
Month	Normal	1979	1980	1981	Normal	1979	1980	1981
May	9.0	+1.3	–1.3	+2.4	34.3	– 7.0	± 0	–17.0
June	14.1	+1.7	+3.0	–1.1	44.5	–18.8	+ 6.7	+71.0
July	17.1	–2.2	±0	–0.3	67.0	+68.6	–29.3	+33.0
August	15.5	+0.4	–0.6	–1.2	71.8	+ 7.8	+30.9	+30.7
September	10.6	–0.6	+0.6	–0.4	58.8	+19.5	+ 6.6	–33.8

Results

The choice of fungicides for the field experiments was based on the results of the pot experiments. In 1979, the early summer was warm and favourable for the disease. The seed dressing experiment in four locations showed on the average 44 % of damping-off in the untreated seed and 44–60 % in treated seed. No difference could be found in the number of healthy seedlings per row meter after the damping-off stage between untreated and treated seed (Table 7).

The average results of eleven experiments showed different seed and spraying treatments to have very little effect on damping-off (Table 8). After the damping-off stage there was an increase in the number of healthy seedlings per row meter of 0.1–0.5 after spraying, as compared with the untreated plot. This was not, however, statistically significant.

In 1980, there were serious outbreaks of damping-off, as was the case in 1979. In the seed dressing experiment there was 67 % damping-off in the untreated plot (Table 9). The pelleted seed showed the lowest percentage of

Table 7. The effect of seed treatment on the damping-off frequency and number of healthy beet plants per row meter in final stands as means of experiment in 4 locations in 1979.

Seed treatment			Number of healthy plants/row meter in final stands
Fungicide	Dosage g a.i./kg seed	Damping-off %	
Untreated	–	44	3.0
Metalaxyl	0.25	56	*Difference from untreated* –0.2
Metalaxyl +thiram	0.25+4.0	44	+0.1
Methoxyethylmercury silicate	0.09	54	–0.2
Propamocarb	18.8	60	–0.6
Propamocarb + thiram	18.8+4.0	55	–0.6
Thiram	4.0	55	0.0
F-value		0.97	0.50

Table 8. The effect of seed treatment and plant spraying on the percentage of damping-off and number of healthy sugar beet plants/row meter in final stands as means of 11 field experiments in 1979.

Treatment					
Seed treatment		Spraying		Damping-off	No. of healthy plants/row meter in final stands
Fungicide	Dosage g a.i./kg seed	Time[1)]	Dosage kg a.i./ha	%	
Untreated	–	–	–	55	2.4
					Difference from untreated
Propamocarb	18.8	–	–	59	±0.0
"	18.8	a	0.5	56	+0.2
"	18.8	b	0.5	58	+0.1
"	18.8	c	0.5+0.5	56	+0.2
"	18.8	d	0.5+0.5	51	+0.5
Propamocarb + tiophanatmethyl	18.8+1.4	–	–	59	+0.2
" "	18.8+1.4	a	0.5+0.2	60	+0.1
" "	18.8+1.4	b	0.5+0.2	56	+0.4
" "	18.8+1.4	c	(0.5+0.2)+(0.5+0.2)	57	+0.3
" "	18.8+1.4	d	(0.5+0.2)+(0.5+0.2)	54	+0.5
F-value				0.08	0.22

[1)] Spraying at emergence
b= " 1 week after emergence
c= " at emergence + 1week later
d= " " " + 2 weeks "

Table 9. The effect of seed treatment on the damping-off frequency, number of healthy beets per row meter in final stands, number of beet roots per ha, yield and sugar content as means of 4 field experiments in 1980.

Seed treatment						
Fungicide	Dosage g a.i./kg seed	Damping-off %	No. of healthy plants/row meter in final stands	No. of[1)] beet roots 1000/ha	Yield[1)] tons/ha	Sugar[1)] Content %
Untreated	–	67	1.8	61.2	35.0	14.10
			Difference from untreated			
Hymexazol	3.5	57	+0.8	+18.6	+4.7	+0.45
Hymexazol	8.4	49	+1.3	+22.0	+4.8	+0.48
Hymexazol	14.0	43	+1.7	+21.1	+4.1	+0.09
Hymexazol + thiram[2)]	18.9+7.0	13	+2.3	+ 6.0	+0.5	+0.45
Dipping in a propamocarb suspension	10 h., 1 %	70	−0.1	+13.9	+6.2	+0.56
Pythium oligandrum biopreparation	160	68	−0.4	− 9.0	−5.4	+0.37
F-value		44.74***	51.38***	18.47***	6.12***	

[1)] Mean of 3 experiments
[2)] Pelleted seed

damping-off, only 13 %. When hymexazol was increased from 3.5 to 14.0 grams per kg seed, the percentage of damping-off fell from 57 to 43 %. The dipping of seed into a propamocarb solution did not lower the percentage of damping-off, and *P. oligandrum* had no protective effect in this respect. The number of healthy seedlings per row meter at the end of June was highest with pelleted seed, 4.1, and lowest with *P. oligandrum* treatment, 1.4. In the untreated plot there were 1.8 healthy seedlings. Seed dressing with hymexazol, 3.5–14.0 g/kg seed, led to an increase of 0.8–1.7 in seedlings/row meter as compared with the untreated seed. The yield in the experiment was quite high, 35 tons/ha on the average. All the treatments except for *P. oligandrum* preparate increased the yield. The dipping of seed into a propamocarb solution increased the yield by 6.2 tons and the treatment of seed with hymexazol by 4.1–4.7 tons. In the autumn, untreated plots produced 61200 beets/ha on the average, whereas plots treated with hymexazol produced about 80000 beets/ha. All seed treatments gave somewhat higher sugar contents than the untreated seed, the highest increase being with propamocarb, 0.56 %, and the lowest with hymexazol, 0.04 %.

In 1980, an experiment was made to study the effect of hymexazol and propamocarb using spraying. Hymexazol was used in two concentrations, 0.5 % and 0.1 %. The spraying of seedlings at emergence gave good control results with the 0.5 % suspension of hymexazol alone and hymexazol in combination with thiram (Table 10). The damping-off percentage fell to 0–12 % as compared with the 40 % in the control, the increase in yield was 1.9–4.2 tons/ha and in the autumn there was an increase of 7100–17400 beets/ha. Propamocarb also increased the yield and controlled damping-off to some extent. In the experiment with 0.1 % of hymexazol there was 78 % of damping-off (Table 10). Seed dressing with hymexazol or propamocarb did not produce healthier stands than untreated seed, whereas with hymexazol + thiram there was only 45 % of damping off. Propamocarb spraying had no effect, yet spraying with hymexazol + thiram decreased damping-off to 17 %. The amount of beet produced was about the same either with spraying or seed dressing. In this experiment, treated seed have higher sugar contents than untreated. Seed dressing with the combimation hymexazol + thiram gave a significantly greater yield.

In 1981, it was colder and rainier during the early stage of seedling development than in 1979 and 1980, and damping-off occurred less frequently than in 1979–1980. That year, two seed dressing experiments were made. In one experiment the control treatment was dressed with thiram and the damping-off percentage was 58 % (Table 11). Using hymexazol, 14.7 g/kg seed, the percentage was much lower and the yield on the average 2.7 tons higher per hectare than in the untreated plot, which produced a yield of 23.7 tons/ha. The effect of seed treatment on the sugar content varied. When the seed was pelleted (Table 12), the effect of seed dressing on the number of healthy seedlings was the same. The increase in the yield was, however, only 0.2–1.5 tons/ha.

In the spraying experiment in 1981, hymexazol showed a good effect on the health of the seedlings. Thiram or propamocarb + benomyl did not give

Table 10. The effect of hymexazol and propamocarb seed treatment and plant spraying on the percentage of damping-off, number of healthy beet plants/row meter in final stands, number of beet roots/ha, yield and sugar content. 4 trials with 0.5 % hymexazol spraying and 4 trials with 0.1 % hymexazol spraying.

Treatment									
Seed treatment		Spraying			Damping-off	No. of healthy plants/row meter	Beet[2] roots	Yield[2]	Sugar[2]
Fungicide	Dosage g a.i./kg seed	Time[1]	Dosage kg a.i./ha		%	in final stands	1000/ha	tons/ha	%
0.5 % hymexazol									
Untreated	–	–	–		43	3.0	63.2	35.7	14.91
						Difference from untreated			
Propamocarb	18.8	–	–		43	+0.4	+2.2	+3,0	−0.13
"	18.8	a	2.0		35	+0.9	+4.2	+1.5	−0.07
"	18.8	b	2.0+2.0		33	+1.0	+1.2	+0.9	+0.32
Propamocarb + benomyl	18.8+1.0	–	–		47	+0.1	+1.4	+1.2	+0.11
" "	18.8+1.0	a	2.0+0.5		34	+0.8	+5.7	+1.4	+0.11
" "	18.8+1.0	b	(2.0+0.5) + (2.0+0.5)		24	+1.4	+5.5	+0.9	+0.25
Hymexazol	8.4	–	–		40	+1.2	+7.1	+3.8	−0.20
"	8.4	a	7.0		1	+3.9	+13.2	+1.9	+0.06
"	8.4	b	7.0+7.0	7.0+7.0	0	+4.2	+17.4	+4.2	+0.14
Hymexazol + thiram	8.4+4.0	–	–		28	+2.5	+11.3	+3.5	−0.10
" "	8.4+4.0	a	7.0+3.0		7	+4.1	+11.9	+3.7	+0.17
" "	8.4+4.0	b	(7.0+3.0) + (7.0+3.0)		12	+3.7	+13.6	+2.3	+0.34
				F-value	11.51***	72.24***	7.09***	1.22	

Treatment								
Seed treatment		Spraying		Damping-	No. of healthy	Beet[2)]		
	Dosage		Dosage	off	plants/row meter	roots	Yield[2)]	Sugar[2)]
Fungicide	g a.i./kg seed	Time[1)]	kg a.i./ha	%	in final stands	1000/ha	tons/ha	%
0.1 % hymexazol								
Untreated	–	–	–	78	1.1	56.8	27.5	14.0
					Difference from untreated			
Propamocarb	18.8	–	–	75	+0.3	+1.2	−0.4	+0.27
"	18.8	a	2.0	70	+0.6	−0.5	−2.9	+0.32
"	18.8	b	2.0+2.0	67	+0.8	+6.1	+0.2	+0.18
Propamocarb + benomyl	18.8+1.0	–	–	75	+0.2	+3.2	−3.6	+0.31
" "	18.8+1.0	a	2.0+0.5	67	+0.6	+3.1	−0.3	+0.20
" "	18.8+1.0	b	(2.0+0.5) + (2.0+0.5)	67	+0.6	+1.1	−2.1	+0.47
Hymexazol	8.4	–	–	78	+0.3	+11.3	−2.0	+0.33
"	8.4	a	1.4	42	+2.6	+16.7	+1.5	+0.52
"	8.4	b	1.4+1.4	39	+2.8	+10.0	+0.7	+0.65
Hymexazol + thiram	8.4+4.0	–	–	45	+2.8	+21.8	+4.4	+0.36
" "	8.4+4.0	a	1.4+3.0	23	+4.4	+22.8	+4.0	+0.47
" "	8.4+4.0	b	(1.4+3.0) + (1.4+3.0)	17	+4.8	+25.7	+4.9	+0.59
			F-value	15.45***	64.72***	13.95***	4.85***	

1) a = Spraying at emergence
b = " " " + 1 week later

2) Mean of 3 trials

Table 11. The effect of seed treatment on the damping-off frequency, number of healthy beet plants per row meter in final stands, number of beet roots per ha, yield and sugar content as means of 4 field experiments in 1981.

Seed treatment						
Fungicide	Dosage g a.i./kg seed	Damping-off %	No. of healthy plants/row meter in final stands	No. of[1)] beet roots 1000/ha	Yield[1)] tons/ha	Sugar[1)] content %
Thiram (control)	4.0	58	2.2	70.3	23.7	15.14
			Difference from thiram-treated			
Hymexazol	8.4	18	+2.5	+16.3	−0.6	+0.05
Hymexazol	10.5	19	+2.8	+20.0	+1.1	+0.38
Hymexazol	12.6	16	+2.8	+23.8	+2.0	+0.38
Hymexazol	14.7	11	+3.1	+31.2	+2.7	−0.05
Metalaxyl	1.5	60	−0.2	+ 1.4	+1.1	−0.37
F-value		103.50***	108.80***	10.26***	1.24	

1) Mean of 2 experiments

Table 12. The effect of seed pelleting with fungicides on the damping-off frequency, number of healthy beet plants per row meter in final stands, number of beet roots per ha, yield and sugar content as means of 4 field experiments in 1981.

Seed treatment						
Fungicide	Dosage g a.i./kg seed	Damping-off %	No. of healthy plants/row meter in final stands	No. of[1)] beet roots 1000/ha	Yield[1)] tons/ha	Sugar[1)] content %
Thiram (control)	4.0	56	2.7	79.5	23.1	15.84
			Difference from thiram-treated			
Hymexazol + thiram	8.4 +4.0	15	+2.6	+ 8.1	−1.2	+0.14
Hymexazol + thiram	12.6 +4.0	5	+3.1	+17.8	+1.5	+0.27
Hymexazol + thiram	16.8 +4.0	3	+3.3	+18.2	+0.2	+0.24
Metalaxyl + thiram	0.25+4.0	55	−0.1	− 3.3	−1.8	+0.19
F-value		229.62***	194.39***	14.46***	2.30	

1) Mean of 2 experiments

the same results (Table 13). Spraying with hymexazol into the seed furrow showed promising (Table 14), although there were some technical problems. The advantage of this method is the fact that only small amounts of fungicide are needed. When the damping-off percentage in the thiram control was 65 %, with hymexazol and thiram seed dressing it was only 31 %, and when spraying hymexazol 0.14 kg/ha into the seed furrow, only 13 %. With 0.84 kg/ha there were no symprtoms of damping-off whatsoever.

In a liming experiment in 1980, limig had little effect on damping-off (Table 15). With 6 tons of lime/ha the number of seedlings per row meter

Table 13. The effect of seed dressing with the combination hymexazol + thiram and spraying on the percentage of damping-off, number of healthy plants/row meter in final stands, number of beet roots/ha, yield and sugar content as means of 4 field experiments in 1981.

Treatment: Seed treatment: Fungicide	Dosage g a.i./kg seed	Spraying dosage kg a.i./ha	Damping-off %	No. of healthy plants/row meter in final stands	Beet[1] roots 1000/ha	Yield[1] tons/ha	Sugar[1] %
Untreated	–	–	55	1.9	80.9	25.3	16.18
				Difference from untreated			
Hymexazol+thiram	10.5+4.0	–	24	+2.2	+ 6.2	+0.9	+0.14
" "	10.5+4.0	hymexazol 2.8	6	+3.1	+14.1	+4.2	+0.09
" "	10.5+4.0	thiram 2.0	19	+2.4	+ 3.4	+0.5	+0.02
" "	10.5+4.0	propamocarb + benomyl 2.0+0.6	19	+2.5	+ 6.6	+1.3	−0.14
F-value			49.84***	28.55***	0.93	0.78	

[1] Mean of 2 experiments

Table 14. The effect of seed treatment with the combination hymexazol + thiram sprayed into the seed furrow on the percentage of damping-off and number of healthy sugar beet plants/row meter in final stands. Field experiment in 1981.

Treatment: Seed treatment: Fungicide	Dosage g a.i./kg seed	Spraying in seed furrow kg a.i./ha	Damping-off %	No. of healthy plants/row meter in final stands
Thiram (control)	4.0	–	65	2.3
				Difference from thiram-treated
Hymexazol + thiram	10.5+4.0	–	31	+2.4
" "	10.5+4.0	Hymexazol 0.14	13	+2.3
" "	10.5+4.0	" 0.84	0	+3.9
" "	10.5+4.0	hymexazol + thiram 0.14 + 0.5	3	+4.9
F-value			50.54***	46.52***
$LSD_{t0.05}$			11.5	0.8

after the damping-off stage at the end of June increased on the average by 0.2, and the percentage of damping-off fell from 51 to 42 %.

In the liming experiment at the end of June 1981, a pH of 6.9 was measured after the "normal liming amount" and after 1.5 times the amount, pH still remained at 6.9, the plots without lime being of pH 6.0. When the damping-off percentage was 69 % without liming, it was 55 % on the average after the larger amount of lime. Liming gave a 1 % increase in the yield, whereas the sugar content fell by 0.22–0.30 %. The compost preparete Eokomit was used together with lime, but it had no additional effect on the incidence of damping-off (Table 16).

Table 15. The effect of lime application and seed treatment on the percentage of damping-off and number of healthy sugar beet plants/per row meter in final stands as means of 4 field experiments in 1980.

Seed treatment		Liming					
		No lime application		Hydrated fine ground lime 3 tons/ha		Hydrated fine ground lime 6 tons/ha	
Fungicide	Dosage g a.i./ kg seed	Damping-off %	No. of healthy plants/row meter in final stands	Damping-off %	No. of healthy plants/row meter in final stands	Damping-off %	No. of healthy plants/row meter in final stands
					Difference from untreated		Difference from untreated
Untreated	–	54	2.3	50	+0.1	53	±0
			Difference from untreated				
Hymexazol	8.4	42	+1.8	35	+2.1	36	+2.0
Hymexazol + thiram	8.4+4.0	44	+1.6	45	+1.4	31	+2.0
Methoxyethylmercury choride	0.09	57	+0.4	57	+0.5	44	+1.1
Propamocarb	18.8	57	+0.2	51	+0.5	41	+1.0
" + benomyl	18.8+1.0	52	+0.3	37	+0.9	41	+1.0
Mean		51	3.2	46	3.2	42	3.4

	F-value	
	Percentage of damping-off	No. of healthy plants/row meter in final stands
Liming	6.81**	4.29*
Seed treatment	10.24***	8.10***
Liming + seed treatment	0.67	0.65

Table 16. The effect of lime application on the percentage of damping-off, number of healthy beet plants/ row meter in final stands, number of beet roots/ha, yield and sugar content as means of 3 field experiments in 1981.

Liming	Damping-off %	No. of healthy plants/row meter in final stands	Beet roots 1000/ha	Yield tons/ha	Sugar %
No lime application	69	1.6	84.5	29.0	15.42
		Difference from untreated			
"Normal application"[1]	60	+0.4	+7.9	+0.2	−0.22
"Normal application" × 1.5	55	+0.5	+5.2	+0.2	−0.25
"Normal application" + Eokomit spraying[2]	55	+0.7	+1.0	+0.3	−0.30
F-value	2.24	1.79	1.87	0.02	

[1] Hydrated fine ground lime application to reach pH 7.5
[2] 2000 l/ha Eokomit suspension

Discussion

Out of several preparations tested, the systemic fungicide hymexazol proved the most effective seed dressor against damping-off of sugar beet. Mercurial compounds and thiram had very little effect. These results are in agreement with those of DARPOUX et al. (1965) and KOCH (1979). The systemic fungicide propamocarb which is effective against *Pythium* species (ANON: 1978) seemed to be to some extent effective against damping-off under certain conditions, i.e. low temperature and moderate outbreaks of damping-off. In a field experiment, dipping of the seed in a solution of propamocarb gave the gratest yield, although the incidence of damping-off was as high as in the control. In this case, therefore, the positive effect of the treatment seems to be due to pre-germination rather than to the fungicide. With regard to the effect of temperature, two greenhouse experiments at 8 °C and 18°C showed the response to seed dressings to increase with decreasing temperature, a fact that is in agreement with the findings of GATES and HULL (1954). At 8°C, the treatment of seed even with mercurial compounds was effective against soil borne damping-off, but at 18°C the effect was negligible. However, under field conditions, only hymexazol and especially hymexazol + thiram proved effective seed dressors. Hymexazol is reported to be effective against a range of soil borne diseases, especially those caused by *Pythium, Fusarium* and *Aphanomyces* (ANON. 1971).

The treatment of the seed with hymexazol + thiram gave, in most cases, very healthy stands and in 1982 this treatment came into commercial use in Finland. In some cases, both in pot and field trials, the incidence of the disease was approximately as high as with untreated seed, but it attacked at a later stage and was not as disastrous as in the control. Chronic damping-off did occur, but the plants recovered pretty well. Hymexazol is not only an effective fungicide against *Pythium* and *Fusarium,* but also an effective plant growth promotor (KUKALENKO & VOLODKOVICH 1979). Both pot and field experiments showed higher amounts clearly to improve the effect of hymexazol. The optimum amount would be about 10 g/kg seed combined with thiram, 4 g. The use of thiram together with hymexazol improved the health of beet stands more than did hymexazol alone. The same was observed by HRUBESH and WIESER (1978) who also recommed mancozeb in this respect.

The effects of soil treatment against damping-off of sugar beet have been investigated in both pot and field trials. Band spraying with hymexazol and thiram, using very great amounts of water (up to 20000 l/net ha), gave almost a 100 % control of the disease. However, the favourable effect of such treatments on the yield in comparison with seed dressing alone was very small except in some districts with very severe outbreaks of the disease. Moreover, spraying treatment requires large amouts of the fungicide to be effective, which is certainly not economically profitable for the farmer. The application of the fungicide, using small amouts, to the seed furrow in connection with sowing gave very good results, but the method needs further development. In conclusion, the treatment of seed with hymexazol + thiram seemed, however, to provide a good protection against the disease.

Preventive control of damping-off by liming gave promising results in a pot experiment. This experiment also showed the response to different seed dressings to rise with increasing soil acidity. In field experiments during 1980–1981, liming had not clearly positive effect on the incidence of damping-off. This, presumably, was due to the fact that the pH did not rise high enough to prevent damping-off caused mainly by *Pythium*.

P. oligandrum is reported to be an effective seed dressor against damping-off caused by *Pythium* (VESELÝ 1978, 1979). However, in this study the Czechoslovakian biological preparation acted more as a pathogen than as an antagonist against *Pythium debaryanum*. Therefore, a successful biological control of damping-off would most probably require organisms isolated from Finnish soils. The biological control of damping-off as a whole needs further investigation.

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Ms received August 29, 1983.

SELOSTUS

Sokerijuurikkaan taimipolte Suomessa. II. Taudin torjunta

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Vuosina 1979–81 tutkittiin Helsingin yliopiston kasvipatologian laitoksen ja Sokerijuurikkaan tutkimuskeskuksen välisenä yhteistyönä sokerijuurikkaan taimipoltteen torjuntaa sekä astia- että kenttäkokein.

Tutkimukset sisälsivät peittauskokeita, peittaus- + ruiskutuskokeita ja kalkituskokeita. Kemiallisten keinojen lisäksi on alustavasti tutkittu myös biologisten torjuntavalmisteiden käyttömahdollisuuksia. Ruiskutukset tehtiin kenttäkokeissa riville juurikkaiden taimelletulovaiheessa ja/tai eri ajankohtina tämän jälkeen käyttäen suuria vesimääriä. Kemiallisiin torjuntakokeisiin valittiin lähinnä sellaisia fungisideja, joilla tiedettiin olevan hyvä teho leväsieniin, mihin sieniryhmään tärkein taimipoltteen aiheuttaja, *Pythium debaryanum*, myös kuuluu. Kalkituskokeissa käytettiin rakennushienokalkkia.

Testatuista fungisideista hymexazolilla oli paras teho taimipoltetta vastaan. Yhdessä tiraamin kanssa teho parani vielä huomattavasti. Optimaalisena käyttömääränä siemenen peittauksessa oli n. 10 g hymexazolia + 4 g tiraamia siemenkiloa kohti. Tällainen siemenkäsittely johti useimmissa kokeissa selvästi terveempiin juurikasvustoihin ja myös huomattaviin sadonlisäyksiin, suurimpien ollessa n. 14 % (esim. 4.8 tonnin lisäsato peittauskokeessa v. 1980). Joissakin tapauksissa hymexazolilla peitatuissa ruuduissa kehittyi tautia saman verran kuin kontrolliruuduissa, mutta tauti tuli myöhemmässä vaiheessa eikä näin ollen ollut kovin tuhoisa. Propamocarb oli hymexazolin jälkeen lupaavin testetuista fungisideista.

Torjunta-aineen ruiskuttaminen riville tai sijoittaminen kylvövaon pohjalle antoi käytännöilisesti katsoen täysin terveitä kasvustoja hymexazolia + tiraamia käyttäen. Käsittely ei kuitenkaan oleellisesti lisännyt sadon määrää pelkkään peittaukseen verrattuna, paitsi joillakin erittäin tautisilla pelloilla. Sijoittamalla hymexazol + tiraami kylvövaon pohjalle saatiin terveitä kasvustoja hyvin pieniäkin torjunta-ainemääriä (0.84 kg/ha) käyttäen. Taimiriveille ruiskuttaminen taimettumisvaiheessa vaatii ollakseen tehokasta suuria torjunta-ainemääriä.

Kalkituksella oli astiakokeessa melko hyvä ennaltaehkäisevä vaikutus taimipoltetta vastaan. Kokeiltujen peittausaineiden teho parani myös maan pH-luvun noustessa. Pelto-olosuhteissa kalkituksen vaikutus oli kuitenkin vähäinen.

Tutkimuksissa alustavasti kokeillut biologiset torjunta-aineet, *Pythium oligandrum* -biopreparaatti ja Eokomit-kompostipreparaatti, eivät antaneet lupaavia tuloksia.