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Storage fungi of onion and their control

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Abstract. *Botrytis allii* Munn caused total onion damages of 15–20 % during storage in 1975–1979, and was present on 80–90 % of the spoilt onions. The proportion of damage caused by *Fusarium oxysporum* Schl. was 0–5 % and was present in 0–10 % of the spoilt onions. The early weight losses during storage of the onions were mostly due to storage pathogens which spread via the onion sets used as propagation material. This can be prevented very effectively by soaking the sets in benomyl solution before planting out. The unusually high fungus content of the sets resulted in a reduced yield. Spraying with fungicide early on in the growing season and applying different amounts of nitrogen fertilizer had no significant effect on the number of storage pathogens. A low stroge temperature did not inhibit the development of storage pathogens, it merely slowed it down.

Introduction

During the last few years, 500–600 ha have usually been under onion cultivation in Finland. Since the Finnish growing season is short, onion sets, which are almost completely (about 85 %) of foreign origin, have to be used for onion cultivation. Holland is the most important supplier. Onions are grown from seed almost exclusively in the Åland Islands over an area of about 130 ha. In countries to the south of Finland, onions to be stored are grown from seed and hence the occurrence and spread of storage pathogens in Finland is likely to be different from that elsewhere.

Studies have been carried out earlier in Finland on onion storage (JAMALAINEN 1962, AURA 1963). However, multiplier onions were almost exclusively used at that time and the low storage temperatures used today had not become common practice. No storage studies have been carried out since onion sets came into common use. According to information provided by onion growers, storage pathogens have caused total onion losses of as high as 50–60 % in modern cold stores. For this reason, storage pathogens are considered to be one of the most serious problems in onion growing.

Right up until a few years ago, *Botrytis allii* Munn, which is the most important storage pathogen of onion, was reported to infect onions in the field, usually close to harvesting time or during harvesting in Finland (JAMALAINEN 1962) and also elsewhere (HEINZE 1974). However, a number of studies have shown that *B. allii* spreads to onions via the seeds and is dormant during the growing season (MAUDE and PRESLY 1977 a).

Fusarium oxysporum Schl. is also a fungus which causes spoilage of onions (WALKER 1952, HEINZE 1974). However, the damage it causes is only slight (BÖTTCHER 1973). This fungus is known to spread via the seeds and sets (PARKINSON and CLARKE 1964, NOBLE and RICHARDSON 1968).

The aim of this study was to determine the most common and most important storage pathogens of onions, their transfer via onion sets, and possible control by means of fungicide treatment of both the sets and the onion plants. The growth capacity of the most important storage pathogens at different temperatures, and the effect of nitrogen fertilization on the number of storage pathogens has also been examined.

Material and methods

Fungal determinations carried out on the onions

The onions in 10 commercial growers' stores in the Turku, Joensuu and Turenki area during the period 1975–78 were studied in order to determine which pathogenic fungi affect onions in store. In addition, onions were grown at Viikki from sets of differing origin in 1976–79, in order to determine what type of fungi are to be found on onions. A total of about 110 000 onions and the storage pathogens growing on them were examined.

In the first year of the experiment, the infected onions were divided into disease classes on the basis of their symptoms. Samples were taken from the demarcation line between diseased and healthy onion tissue and then surface sterilised in 1 % sodium hypochlorite. The pieces of plant tissue were then transferred to PDA medium and also to moist filter paper in petri dishes. In subsequent years, onions spoiled by *Botrytis allii, Fusarium oxysporum, Aspergillus niger* and *Penicillium* spp. were classified directly by eye or through examination under a stereo-microscope. In all uncertain cases, however, pieces of onion tissue were removed from the border between diseased and healthy tissue for incubation on damp filter paper followed by examination under the microscope.

Fungal determinations carried out on the onion sets

The fungi present on onion sets intended for field trials, as well as the degree of infection, were determined by incubating bisected onion sets, which had first been surface sterilised in 1 % sodium hypochlorite, on filter paper in petri dishes (Ø=14 cm) for 10 days. The fungi were identified under a stereo-microscope and, whenever necessary, also under an ordinary research microscope. The degree of infection by *Aspergillus niger, Fusarium oxysporum* and *Penicillium* spp. was estimated using a 0–3 classification, in which 0 = healthy and 3 = fungus covering 1/2 of the cut surface of the set. 60 sets were examined from each lot. Altogether 67 onion lots were checked in 1977 and 16 in 1978, the sets being selected from the onion lots shown in Figs. 1, 3 and 4. Preliminary experiments were carried out in 1976 to determine the best methods to be used and the type of fungi to be found on the sets (TAHVONEN and RIIKONEN 1977, RIIKONEN 1978). The results obtained in these preliminary experiments are not presented here because they are in agreement with those obtained in 1977–78. The onion lots depicted in Figs. 3 and 4 have

been grown from domestic and foreign 'Stuttgarter Riesen' sets, 15—22 mm in size. The onion lots shown in Fig. 1 also include some other planting sizes and varieties.

Control and nitrogen fertilization experiments

The sets used in the storage pathogen control experiments were soaked for 15 minutes in a benomylsolution (0,2 % Benlate preparation). Five different fungicides were used in spraying the onion plants: benomyl (Benlate, 1.2 kg/ha), thiophenate methyl (Topsin M, 1.4 kg/ha), tolylfluanide (Euparen M, 5.0 kg/ha), captaphol (Difolatan 80 WP, 1.6 kg/ha) and vinclozolin (Ronilan, 1.5 kg/ha) mixed in 2000 l water/ha. Spring sprayings were carried out when the shoots were 10—15 cm high and the second spraying after one week. Autumn sprayings were carried out 2 weeks and 2 + 1 weeks before harvesting. Sprayings carried out in the other experiments are shown in the tables.

The effect of nitrogen fertilization on the storage pathogens of the onion crop in onion set and onion cultivation was followed by fertilizing with 1000 or 1150 kg chloride-free mixed fertilizer ($N:P_2O_5:K_2O$ = 7:24:14)/ha. The highest nitrogen levels were obtained by adding the required amounts of nitrogen as calcium nitrate. The sets grown in the onion set experiment were graded after storage into size classes of 10—15 mm and 15—22 mm, and then planted in a normally-fertilized (see other experiments) field without any fungicide treatment. From 1200—1400 kg/ha chloride-free mixed fertilizer was used in the other experiments. All the fertilizers, including nitrogen, were applied as row fertilization before planting out. The nitrogen fertilizer and control experiments (POHTO 1979) carried out in 1976, which were pilot experiments for those carried out in 1977—78 and whose results and methods were the same as those used in 1977—79, will not be dealt with here. The onion plants used in the spraying experiments carried out in Viikki in 1977 (Tables 3 and 4) were inoculated five times, starting from the middle of July, at intervals of two weeks, by spraying them with a suspension of *Botrytis allii* at a level of 600 l/ha (one 9 cm-petri dish containing *B. allii* on PDA medium /l H_2O).

The variety, 'Stuttgarter Riesen' was used in all the control and nitrogen experiments apart from those carried out in 1975 using variety 'Superbunt'.

The temperature experiments

In the temperature experiments, storage at — 1°C and + 1°C was carried out in a mechanically cooled store where the temperature variation vas ± 0.5°C. Storage at 2—8°C was done in a store cooled by means of outside air and that at 20°C in and ordinary room where the temperature variation vas ± 2°C. The onion sets to be grown in the temperature experiment were artificially inoculated before planting with a suspension of *Botrytis allii* and *Fusarium oxysporum* in order to ensure that the crop would be infected.

The growing and storing methods of onions

The experiments carried out at Viikki were planted by hand. At Turenki, where the experiments were carried out in the fields and store of a commercial grower,

planting was done by machine. Planting was carried out in different years during the period 15.–25. 5. and the crops harvested during 18.–25. 8.

All the onions from the experiment were placed, after harvesting, into net bags without removing the stalks and then mechanically dried in circulating air at 25–30°C for 5–10 days. During storage the air was continuously drawn over the onions by means of a fan in order to remove excess moisture. An effort was made to replicate, as far as possible, the conditions prevailing in normal onion stores, where 500–700 m^3 air $tn^{-1}h^{-1}$ are used in drying and 100–200 m^3 $tn^{-1}h^{-1}$ in storing.

Statistical methods

The results of the control and nitrogen fertilization experiments have been tested by means of variance analysis or the t-test. The effect of the degree of fungal infection on the sets, which consists of the summed values for *Aspergillus niger, Fusarium oxysporum* and *Penicillium* spp., on the yield, and the effect of the *Botrytis allii* and *Fusarium oxysporum* levels of the stored onions on the weight loss has been depicted and tested by means of the regression equations, $y = bx + a$ or $y = \alpha e^{\beta x}$ and the correlation coefficients.

Results

Storage fungi of onions

Botrytis allii Munn

B. allii was usually found in 80–90 % of the completely spoilt onions (Table 1). The proportion of the fungus on spoilt onions in the different onion lots varied from 56 to 100 %. The total losses caused by this fungus in the different onion lots varied, in the absence of the control treatment, from 5 to 30 %, usually being 15–20 %. The frequency of occurrence of the fungus in the commercial grower's stores was of the same order of magnitude.

The losses in weight of the onions during storage, caused by evaporation throught cell respiration and the effect of the storage pathogens, was explained very well by the degree of infection by *B. allii* alone. In 1977, the correlation between the *B. allii* -% and the percentage weight loss was 0.958^{xxx} and in 1978, 0.966^{xxx}. When the *Fusarium oxysporum* content was included, the weight losses caused by factors other than these two pathogens was, during long-term storage, less than 10 % (Fig. 1). A degree of overall infection of 40 % even caused weight losses of about 30 %.

B. allii was also the most common fungus found in the onion sets. The fungus was found in 15 % of the set lots in 1977 and in 69 % in 1978. The fungus contents varied from 2 to 74 %. However, it was difficult to identify *B. allii* on the onion sets because the presence of many other species of fungi on the sets inhibited or made identification of *B. allii* difficult. When sets were artificially infected with *B. allii* for the temperature experiments, the fungus was not even found on non-surface-sterilised sets and it was not until the onions had been stored at the end of the growing season was the fungus found. Surface sterilisation of the sets with sodium hy-

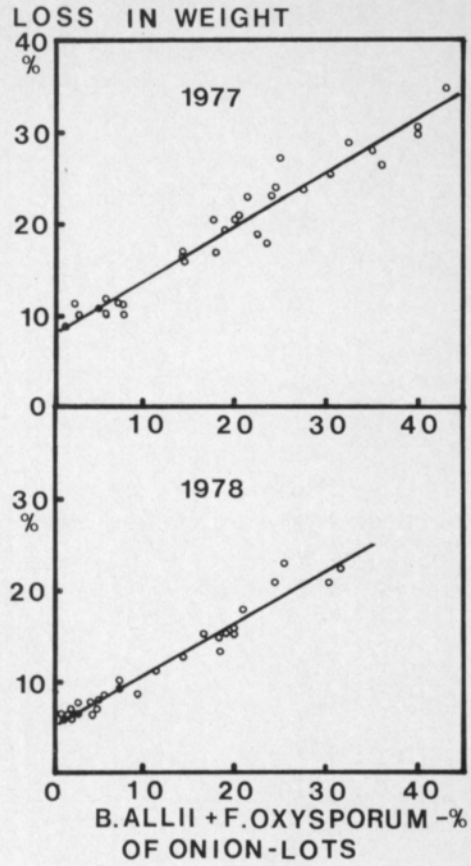

Fig. 1. Effect of storage fungi of onions on weight losses after storage for 7 months (1977) and 6 months (1978).
1977: $y = 0.583\ x + 8.15$, $r = 0.971^{xxx}$
1978: $y = 0.574\ x + 4.94$, $r = 0.977^{xxx}$

Table 1. Effect of soaking onion sets in benomyl on the size and storability of the crop in 1977 (9 onion lots) and in 1978 (12 onion lots). Storage time of 7 and 6 months respectively. 240 onions/lot. Viikki.

Yield and spoilage agent	Untreated sets		Sets soaked in benomyl		t-value
	Mean	Variation	Mean	Variation	
		1977			
Yield, tn/ha	22.2	16.1.–30.3	23.6	17.2–28.3	0.44
Total spoilage-%	26.2	19.7–46.4	5.7	2.0– 9.3	6.2***
Botrytis allii-%	20.8	14.2–32.0	3.8	2.0– 4.6	6.7***
Fusarium oxysporum-%	3.8	0.7– 8.0	0.6	0– 1.3	3.8***
		1978			
Yield, tn/ha	26.9	22.9–34.6	32.7	23.3–36.7	2.4**
Total spoilage-%	18.9	5.7–33.2	4.8	1.9–10.1	4.8***
Botrytis allii-%	17.4	5.2–31.6	4.4	1.9– 9.6	4.8***
Fusarium oxysporum-%	0	–	0	–	

pochlorite in the preliminary experiments in 1979 did not reduce the *B. allii*-% in fungus analyses carried out on naturally infected sets (RIIKONEN 1977).

B. allii was not found to have spread from infected onions to healthy ones during storage when moisture was removed effectively by means of ventilation. In field trials in which the distance between the sample plots was 0.8 m, the fungus was not found to have spread significantly in a single case during the growing season from an infected, unsoaked onion lot to a healthy or benomyl-soaked lot (Tables 1 and 2).

Table 2. Effect of spraying onion plants on *Botrytis allii* levels in the stored crop. 240 onions/sample unit. Viikki, 1975.

Set treatment	Onion plant spraying: Preparation	Onion plant spraying: Days before harvesting	*B. allii*-% after 6 and 7 months storage, mean
Untreated	–	–	38.5
Soaked in benomyl	–	–	0.5
–"–	benomyl	10	2.0
–"–	–"–	7	4.5
–"–	–"–	3	0.3
–"–	thiophanatemethyl	10	1.0
–"–	–"–	7	0.5
–"–	–"–	3	3.0

Fig. 2. Onions spoilt by *Botrytis allii*.

The symptoms produced on the onions by the pathogen (Fig. 2) and also the microscopic characteristics of the pathogen were the same as those described in the literature (ELLIS and WALLER 1974).

Fusarium oxysporum Schl.

The proportion of *F. oxysporum* on completely spoiled onions varied from 0—48 %. However, it was usually below 10 %. The total losses during storage of onions not treated with the control measures varied from 0—15 %, generally being less than 5 % (Fig. 3). The damage percentages in the commercial grower's stores were similar to those obtained in the experiments at Viikki. The fungus was not found to have spread from infected onion lots to healthy ones during the growing season or during storage.

F. oxysporum was exceedingly common in the onion set lots studied, the degree of infection varying from 1.7 to 100 %. The proportion of heavily infected (class 3) sets was, however, mostly under 20 %. There was clear positive correlation between the number of heavily infected sets and the *F. oxysporum* -% of the stored onion crop (Fig. 3). Severe *Fusarium* infection on the sets, together with severe infection by *Aspergillus niger* and *Penicillium*, brought about a decrease in the onion yield (Fig. 4).

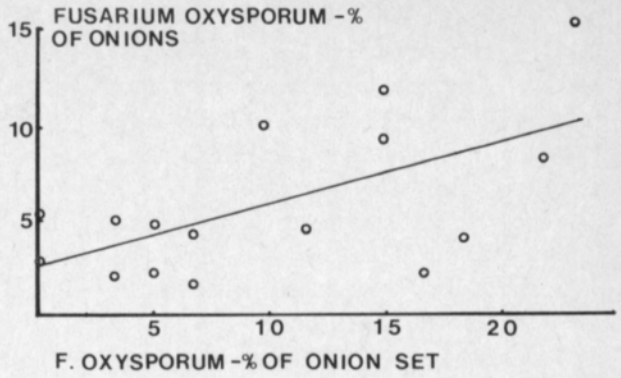

Fig. 3. Effect of *Fusarium oxysporum* -% of sets (infection degree 3) on the *F. oxysporum* -% of the onion crop after storage for 5 months in 1977.
$y = 0.307\ x + 2.8$, $r = 0.61^{xx}$

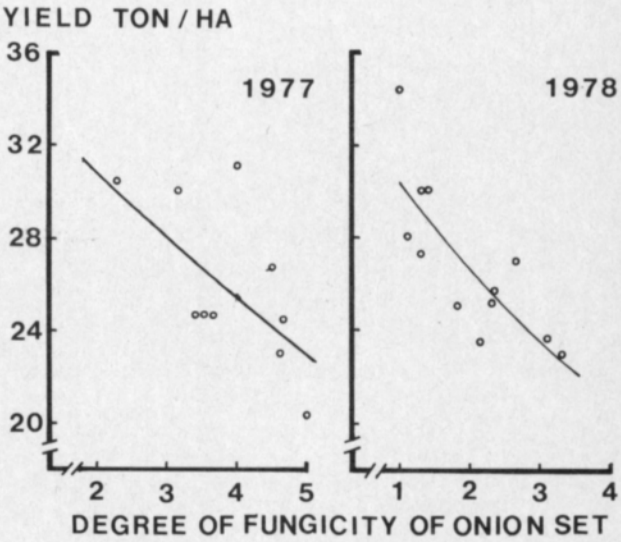

Fig. 4. Effect of summed *Aspergillus niger*, *Fusarium oxysporum* and *Penicillium* spp. degrees of infection of sets on size of onion srxp.
1977: $y = 37.7\ e^{-0.0987x}$, $r = 0.60^{x}$
1978: $y = 34.4\ e^{-0.1270x}$, $r = 0.81^{xxx}$

Fig. 5. Onions spoilt by *Fusarium oxysporum*.

Spoilage caused by *F. oxysporum* started as rotting of the short and flattened stem of the onion, which continued to spread upwards along individual scale leaves. The dry outer scale leaves were more reddish-brown than usual. The infected tissue of bisected onions initially appeared waterish and later desiccated and shrunken starting from the base. Light coloured mycelia were often abundant in the region where the leaves joined the stem (Fig. 5).

The pathogen produced exactly the same symptoms on the sets as on the large onions. When storage of onion sets at a temperature of 25—38°C was terminated, the infected sets were mummifieded and became separated out during the cleaning and grading of the crop. The sets at this stage usually appeared to be healthy. When the sets were grown in the field, the pathogen caused premature death of the roots and yellowing of the leaves when the seeds had been inoculated with a suspension of *F. oxysporum* prior to sowing.

The microscopic appearance of the fungus was the same as that described in the literature (BOOTH 1971).

Other fungi

Aspergillus niger v. Tiegh. was common (21—29 % of infected lots) in one of the joint stores of the commercial grower. However, it was only found occasionally in the other stores, where it grew as black mold on the outermost leaves without completely spoiling the onions (Fig. 6). *A. niger* was common on the sets (83 % of the lots), usually occurring on the surface of the sets and in some lots as an exceedingly abundant systemic pathogen. In such cases it had, together with other fungi, a reducing effect on the size of the crop (Fig. 4).

Penicillium spp. occurred widely on the surface of onions, usually reducing, however, the quality only. Only in a few individual cases did it completely spoil the onions. *Penicillium* fungi were also common in all the set lots. The degree of infection showed considerable variation: the fungus occurred only on the surface of the sets or

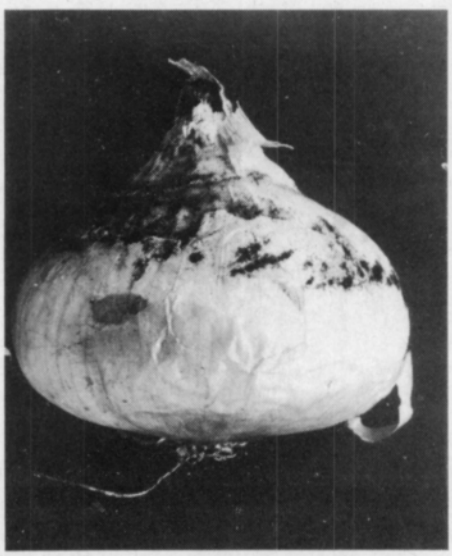

Fig. 6. Black mycelial growth of *Aspergillus niger* on the surface of onions.

penetrated systemically throughout the inside of the sets, in which case spoilage was rapid during inspection and the yield of the sets was smaller than normal.

In addition to the above-mentioned species, the following were also found on stored onions: *Botrytis cinerea* Pers., *Fusidium* sp., *Gliocladium* sp., *Mucor* spp., *Papulospora* sp. and *Trichoderma viride* Pers. ex Fr. The list of species found on the small sets, including all those mentioned above, was as follows: *Acremoniella atra* (Corda) Sacc., *A. verrucosa* Tognini, *Alternaria* spp., *Aspergillus* spp., *Chaetomium* sp., *Chrysosporium* spp., *Cladosporium* spp., *Fusarium avenaceum* (Corda ex Fr.) Sacc., *F. culmorum* (W. G. Smith) Sacc., *F. graminearum* Schwabe, *F. moniliforma* Sheldon, *F. poae* (Peck) Wollenweber, *F. semitectum* Berk. & Rav., *Mycotypha* sp., *Myxomycetes* sp., *Rhizoctonia solani* Kühn., *Rhizopus nigricans* Ehrenb., *Sordaria* sp., *Stachybotrys atra* Corda, *Stemphylium botryosum* Wallr., *Stysanus* sp., *Trichothecium roseum* Link ex Fr., *Tritirachium* sp., *Ulocladium consortiale* Simmons and *Verticillium* spp. None of these fungi were found to have any significant effect on the storability of the onions or on the usability of the sets.

Control of storage fungi of onions

Effect of soaking onion sets in benomyl on storage fungi

Soaking onion sets in benomyl alone before planting out, almost completely inhibited onion spoilage during storage throughout the course of the experiments (Tables 1 and 2). The degree of *B. allii* infection on the soaked onion sets was always less than 5 % at the end of the storage period apart from two lots of onions in 1978 when treatment reduced the *B. allii-%* from 25.7. to 7.5 and 31.6 to 9.6. Soaking in benomyl almost completely protected the onions against *Fusarium* rot. The fungus was not found at all in six treated lots in 1977 and in the other four lots at levels of less than 2 %. *Fusarium* rot was not found at all in the 1978 material (Table 1).

Effect of fungicide treatment in the field on Botrytis allii

Spraying the onion plants during the growing season, in the spring or the autumn, did not reduce damage caused by *B. allii* during storage. The reduction in the *B. allii-%* was only of the order of 1—3 %-units and in these cases only when the onion sets were healthy or soaked before planting in benomyl (Tables 2, 3, 4 and 5).

Table 3. Effect of soaking the sets in benomyl and spraying the onion plants on the *Botrytis allii* levels of the crop after 6 months storage. Plants artificially infected with *B. allii*. 480 onions/sample unit. Viikki, 1977.

Set treatment	Time interval between spraying and harvesting, weeks				
	0	2	2+1	9+7+5+3+1	$\bar{x}$
			B. allii -%		
Untreated	13.0	10.6	6.6	6.3	9.1
Soaked in benomyl	6.9	4.3	5.4	3.3	5.0
$\bar{x}$	10.0	7.5	6.0	5.0	

F-values: soaking sets = 13.3^{x}, sprayings = 8.24^{xx}, combined effect = 2.54

Table 4. Effect of spraying onion plants with fungicide on the *Botrytis allii* levels of the crop after 6 months storage. Plants artificially infected with *B. allii*. 480 onions/sample unit. Viikki, 1977.

Date of treatment	Untreated	Benomyl	Thiophanate-methyl	Tolylfluanide	Captaphol	Vinclozolin	$\bar{x}$
			B. allii -%				
1 week before harvesting	13.0	8.9	15.7	8.0	7.6	11.5	10.8
2 weeks before harvesting ...	13.0	10.6	6.8	10.0	7.4	7.5	9.2
1 +2 weeks before harvesting .	13.0	13.1	5.0	12.9	9.1	9.2	9.8
$\bar{x}$	13.0	10.9	9.1	10.3	8.0	9.4	

F-values: treatment date = 3.8, control chemical = 2.78

Table 5. Effect of nitrogen fertilization and spraying onion plants in spring and autumn on the *Botrytis allii* levels of stored onions. 400 onions/sample unit. Turenki.

N-level kg/ha	Duration of storage, months	Untreated	Spraying plants: One spring spraying	Two spring sprayings	One autumn spraying	Two autumn sprayings	$\bar{x}$
			B. allii -%				
			1977				
80	5	5.0	3.3	3.5	3.3	4.7	4.0
120	5	5.0	3.8	2.3	5.2	7.8	4.8
180	5	5.9	4.4	14.1	3.4	4.9	6.5
	$\bar{x}$	5.3	3.8	6.6	4.0	5.8	5.1
80	8	5.4	4.4	3.4	3.3	5.3	4.4
120	8	6.4	4.1	1.0	5.1	5.3	4.4
180	8	4.3	4.1	2.3	2.7	3.2	3.3
	$\bar{x}$	5.4	4.2	2.2	3.4	4.6	4.0
			1978				
120	7	5.2	3.5	2.7	6.4	2.9	

F-values: 1977: 5 months storage; N = 1.1, treatment = $2.7^{(x)}$,
combined effect = < 1, 8 months storage; N = <1,
treatment = 6.39^{xxx}, combined effect = 2.32^{x}
1978: treatment = 4.5^{x}

Table 6. Effect of nitrogen fertilization and spraying carried out 10 days before harvesting on *Botrytis allii* levels of onions stored for 8 months. 400 onions/samle unit. Turenki, 1975.

Nitrogen fertilization, kg N/ha	Spraying plants: Untreated	Benomyl	Thiophanatemethyl	$\bar{x}$
		B. allii -%		
70	20	7	9	12.0
110	21	10	15	15.3
180	22	12	11	15.2
$\bar{x}$	21.0	9.7	11.7	

F-values: N = 1.92, sprayings = 10.03^{xx}

Table 7. Effect of spraying onion set plants with benomyl and applying different dosages of nitrogen fertilization on the *Botrytis allii* levels of onions after 6 months storage. 850 onions/sample unit. Turenki, 1976–78

Size of sets, mm	Nitrogen fertilization of onion sets in 1976 kg N/ha		Benomyl treatments of onion sets in 1976					
			Untreated	One spring spraying	Two spring sprayings	One autumn spraying	Two autumn sprayings	$\bar{x}$
			B. allii -% after storage 1977/78					
10–15	80		5.4	5.2	8.2	6.6	8.2	6.7
	120		6.9	9.9	6.3	8.2	10.9	8.4
	180		8.0	6.1	6.4	7.1	9.6	7.4
		$\bar{x}$	6.8	7.1	7.0	7.3	9.6	7.6
15–22	80		10.8	9.5	11.5	9.5	12.2	10.7
	120		11.9	12.9	8.9	11.2	16.2	12.2
	180		12.0	7.0	9.8	15.0	12.3	11.2
		$\bar{x}$	11.6	9.8	10.1	11.9	13.6	11.4

F-values: Set size = 26.6^{xxx}, 10–15 mm of sets: N = 4.62, sprayings = 5.70^{x}, combined effect = 2.80^{x}, 15–22 mm of sets: N = 0.74, sprayings = 2.28, combined effect = 1.72.

When the sets were severely infected by *B. allii* or else *B. allii* had been spread over the plants a number of times, treatment of the plants with fungicide reduced the *B. allii-%* of the stored onions (Tables 3 and 6). Spreading *B. allii* a number of times increased the difference between the *B. allii-%* of the untreated sets and those soaked in benomyl by only 4 %-units, although the plants were kept continuously in a moist condition by means of irrigation. There was no difference between the *B. allii-%* of onion sets soaked only in benomyl and those which were not soaked but sprayed with fungicide a number of times (Table 3). When onion sets were being grown, spraying the plants with fungicide in spring and in autumn did not reduce the *B. allii-%* of the following year's crop. Onions grown from the smallest onion sets were healthier than those grown from the largest (Table 7).

Effect of nitrogen fertilization and storage temperature on storage fungi

Application of nitrogen fertilizer to the sets and onions had no effect at all on the storage fungi of onions throughout the course of the experiments (Tables 5, 6 and 7). A high storage temperature of 20°C increased the proportion of *F. oxysporum* among the storage fungi. Spoilage of onions caused by *B. allii* during storage at temperatures below 0°C occurred at a slightly slower rate and at a lower level than at the highest temperature (Fig. 7). In the preliminary trials carried out in 1976, *B. allii* inoculated on healthy onions also grew at temperatures below 0°C, but *F. oxysporum* only caused onion spoilage at temperatures above 0°C (POHTO 1979).

Discussion

The results of these experiments show that *Botrytis allii,* which was clearly the most serious storage pathogen of onions, primarily spreads to the onion crop via the sets. This is in good agreement with recent studies in which *B. allii* was shown to be

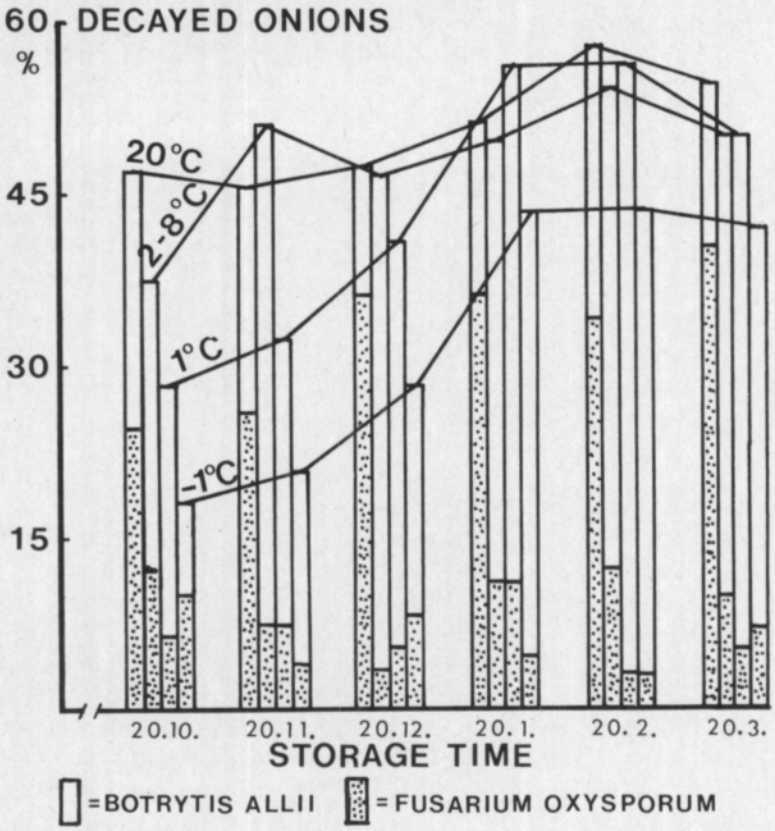

Fig. 7. Effect of different storage temperatures and duration of storage on the storability of onions severely infected by *Botrytis allii* and *Fusarium oxysporum*.

seed-borne and cause latent infection that breaks out as the disease during storage (TICHELAAR 1971, BRÄUTIGAM 1977, MAUDE and PRESLY 1977a, b, BOCHOW and BÖTTCHER 1978, BOCHOW and EL-MOSALLAMY 1979). When the two-year cultivation method was used, the sets were latently infected from infected seed during the first growing season. Infection by *B. allii* does not become apparent during storage of the sets because they are presumably too young physiologically for the fungus to develop (cf. BOCHOW and EL-MOSALLAMY 1979).

In contrast to previously-held beliefs (JAMALAINEN 1962, HEINZE 1974), *B. allii* was not found to infect onions to any significant degree during the growing season, despite the fact that the plants were artificially infected with the fungus and irrigated in order to maintain a high degree of moisture. Furthermore, according to MAUDE and PRESLY (1977 b), infection during the growing season is only slight. The coloured outer scale leaves of onions have been found to stimulate *Aspergillus niger* and to inhibit *B. allii* (HATFIELD et al. 1948). The young tissue of onions (the middle leaves) are more resistant than the older leaves lying under the coloured outer leaves (BOCHOW and EL-MOSALLAMY 1979). Both these feature well explain why the onions were not infected by the end of the growing season and not even when artificially infected in the field. *B. allii* infection did not occur during harvesting on any untopped onions which were dried immediately after being lifted, al-

though there were large numbers of the pathogen's conidia on the surface of the plants.

The possibilities of infection taking place from the soil and the effect of late harvesting or mechanical damage, such as mechanical harvesting, on infection by *B. allii* were not investigated in this study. They will be dealt with in further studies.

The other storage fungi studied in this investigation are of only slight importance in Finland. *Aspergillus niger* and *Penicillium* fungi are mainly pathogens which only reduce the quality of the onion crop. *Fusarium oxysporum,* however, may cause a certain amount of damage in stores in isolated cases. The fungus is presumably only set-borne in Finland, because the fungus requires much higher temperatures than are to be found in Finland to infect onions from the soil (ABAWI and LORBEER 1972).

The reduction in the size of the crop caused by set-borne *Aspergillus, Fusarium* and *Penicillium,* when present in large numbers, is presumably of more importance than the storage diseases caused by these pathogens. In favourable conditions, *F. oxysporum* causes damping-off (ABAWI and LORBEER 1971, 1972) and reaches the stem via the roots (PARKINSON and CLARKE 1964), thus reducing onion growth by killing off the roots prematurely. The fungus can even spoil the onions in the field (WALKER 1952). *Penicillium* has been found to weaken the growth of garlic (SMALLEY 1954), the growing of which resembles that of onion sets. According to the experiments carried out in this study, the high degree of moldiness on the sets is the cause or the result of some other factor producing the poor yield of the sets. For this reason, attention is also nowadays paid to these fungi in Finland in the quality control of sets, the levels of these fungi on severely infected sets not being allowed to exceed 10 %.

The most effective and only suitable method for controlling storage fungi of onions was found to be soaking the sets in fungicide before planting. Benomyl and thiophanatemethyl preparations have been approved in Finland for this purpose. The effectiveness of soaking the sets in fungicide appears to be the same for seed dusting in annual cultivation (MAUDE and PRESLY 1977 b, BOCHOW and BÖTTCHER 1978, WARD 1979).

When the storage fungi of onions are controlled by carefully soaking the sets, a healthy crop can, according to the results of this study, easily be stored in a well-ventilated store from one growing season to the next. Instead of using expensive, mechanically refrigerated stores, cheaper means of storage which employ the outside air for cooling purposes can be used since infected onions will also spoil in cold stores at the lower recommended storage temperatures (cf. AURA 1963). The storability of the onions can be estimated already in the autumn by determining the *B. allii* content of a sample of onions taken from the crop. This study has given very clear hints about this: the main storage losses of onions are caused by *B. allii,* the fungus passes to the store from the field in onions which are already infected and no longer spreads during storage. The preliminary experiments which have been carried out upto now on the estimation of storage capacity have given rather reliable results. Further studies will be carried out by developing methods which the grower himself can easily and surely perform to determine the state of health of the onion crop. The most suitable storage time can then be estimated.

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SELOSTUS

Sipulin varastotaudit ja niiden torjunta Suomessa

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Sipulin varastotaudit ovat olleet taloudellisesti tärkein tautiryhmä sipulin viljelyssä. Sipulin harmaahome ja muut varastotaudit ovat pahimmillaan aiheuttaneet yksittäisille viljelijöille jopa 50—60 %:n sadon menetyksiä. Sen jälkeen kun ryvässipulin viljelystä oli siirrytty pikkuistukkaiden käyttöön ja nykyiset koneellisella läpivirtaustuuletuksella varustetut sipulivarastot olivat yleistyneet, ei varastotauteja ja niiden torjuntaa ole Suomessa perusteellisemmin tutkittu. Vuonna 1975 aloitettiin Helsingin yliopiston kasvipatologian laitoksella sipulin varastotauteja käsittävä tutkimushanke, jossa pyrittiin selvittämään tärkeimmät taudinaiheuttajat, niiden kulkeutumis- ja leviämistiet sekä mahdolliset torjuntamenetelmät.

Varastotautien aiheuttajien ja niiden määrien selvittämiseksi tutkittiin näytteitä viljelijöiden sipulivarastoista ja kasvatettiin sipuleita varastokokeisiin eri alkuperää olevista istukkaista, joista määritettiin myös mukana kulkeutuvat sienet. Varastotautien torjumiseksi tehtiin ennen istutusta istukkaiden torjunta-aineliotuksia ja ruiskutuksia kasvukaudella eri aikoihin ja eri aineilla. Eri typpimäärien ja varastolämpötilojen vaikutusta varastotauteihin tutkittiin.

Sipulin harmaahome (*Botrytis allii* Munn) oli yleisin ja taloudellisesti merkittävin varastotauti, jonka aiheuttamat tappiot vaihtelivat 5—40 %:iin ollen keskimäärin 15—20 %. Sipulin *Fusarium*-mädän (*Fusarium oxysporum* Schl.) osuus varastotuhoista oli 0—15 % ollen yleensä alle 5 %. Muita varastotauteja olivat mustahome (*Aspergillus niger* v. Tiegh.) ja viherhome (*Penicillium* spp.), jotka alensivat pääasiassa vain sipulin laatua.

Sipulin varastotaudit levisivät lähes yksinomaan sairaan pikkuistukkaan mukana. Tästä syystä istukkaan huolellinen liotus 15 minuuttia 0.2 %:ssa Benlate-valmisteessa torjui lähes täydellisesti varastotaudit. Istukkaiden runsas homeisuus alensi huonon säilyvyyden ohella myös sadon määrää.

Kasvukauden aikana sekä keväällä että syksyllä tehdyt useatkaan ruiskutukset benomyyli-liotetuille istukkaille eivät vähentäneet tai vähensivät ainoastaan 1—3 %-yksikköä varastotautien määrää verrattuna pelkkään benomyyli-liotukseen. Pikkuistukkaiden kasvatuksessa tehdyillä kasvuston käsittelyillä ei myöskään ollut vaikutusta seuraavan vuoden sipulin varastotauteihin.

Eri typpilannoitemäärät eivät vaikuttaneet sipulin varastotauteihin. Alhaiset, alle 0°C:n varastolämpötilat hidastivat tautien puhkeamista, mutta eivät estäneet niitä. Tehokkaasti tuuletetussa, mutta vain viileällä ulkoilmalla jäähdytetyssä + 1—8°C:n varastossa terve sipuliaineisto säilyi moitteettomasti ilman merkittäviä tappioita toukokuulle asti.

Suoritettujen kokeiden aikana on myytäville pikkuistukkaille asetettu vaatimukset, jotka vaarallisten kasvintuhoojien lisäksi huomioivat myös istukkaiden käyttöarvoa alentavat kasvitaudit. Lisäksi istukkaiden liotukseen on hyväksytty käytettäväksi benomyyli- (Benlate) ja tiofanaattimetyylivalmiste (Topsin M) varastotautien torjumiseksi.