Final Report
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Leeks: fungicides and disease forecasting for control of rust.

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Practical Section for Growers

Rust is a major problem in leek production and the disease has become increasingly prevalent in recent seasons. The intensification of cropping means that leeks are present throughout the year and this has undoubtly contributed to increased disease pressure. Reliance has been placed on routine fungicide usage but the degree of control is dependant on the efficacy of the fungicide and its persistance on the crop. Increasingly growers are having to adopt highly intensive spray programmes often at times of the year when weather conditions limit the number of spray opportunities. Under these conditions fungicides which are less effective in controlling leek rust may give poor control particularly where rust is well established. Application of fungicides with greater efficacy in controlling rust infection may reduce the need for routine applications or provide some flexibility in the timing of application.

Fungicides which have approval for control of leek rust are Corbel/Mistral (fenpropimorph), Bayleton (triadimefon) and Tilt (propiconazole). When these were compared to a range of new products which had been registered for control of other species of rust on other agricultural crops they were found to give relatively poor control. Most new products tested showed a high level of activity against rust spore germination suggesting that they possess strong protective action.

The post-infection activity of fungicides such as Anvil (hexaconazole) or Folicur (tebuconazole), in glasshouse tests, was also significantly greater than either Corbel or to a lesser extent Tilt. Both Anvil and Folicur could be applied up to seven days after infection had occurred and still maintain almost complete control. The most effective approved product in controlling infection was Tilt although Bayleton (tested as its field equivalent Bayfidan) was not used in the glasshouse studies over the same concentration range. Corbel was relatively ineffective in controlling rust when applied after infection had occurred.

Several other fungicides tested were as effective as Tilt; these included Sanction (flusilazole), Patrol (fenpropidin) and Topaz (penconazole). However some of these products produced toxic reactions on leek leaves under glasshouse conditions. Further field testing of all products is required to confirm their efficacy in controlling rust infection.

Introduction

The leek rust pathogen *Puccinia allii* (DC.) Rud. can be easily recognised on leek leaves. The orange pustules are often found along the axis of the leaf and measure up to 10 mm in length (Jennings *et al.*, 1990). Pustules are often raised and ellipsoidal; when mature, they rupture to release urediniospores which are the infective propagule in leek crops. Urediniospores range in size from 30-36 x 24-29 μm and are dispersed by wind or rain; they can survive for several days under adverse conditions. The pathogen also forms dark grey to black pustules on leeks which contain the teliospore stage of the life cycle. However this stage occurs only after prolonged high temperatures under summer conditions and is probably not epidemiologically significant. Infection often builds up to high levels on leaves depending on the occurrence of favourable weather conditions. The presence of pustules on the leaves considerably reduces the market value of the crop. Severe infection can also result in direct yield loss.

The leek rust pathogen is a major problem limiting leek production in the U.K. and in Europe (Dobson, 1986). Although differences in susceptibility between cultivars exist (Uma & Taylor, 1991, Smith & Crowther, 1992), those used in commercial production are generally susceptible and are chosen on the basis of agronomic characteristics and appearance. New cultivars are regularly introduced (Uma & Taylor, 1991) although there is little information on their relative resistance to the disease. Under these circumstances, and with the increasing intensification of production,

Leek rust infection can occur over a temperature range of 5-32 °C and free water is required for infection to occur. Varying periods of leaf wetness are required over this temperature range if infection is to occur, however at optimal temperatures of 15-20 °C only 5 h of wetness can lead to high infection levels. Visible symptom development on the host occurs 12-16 days after infection however this period of latency can be prolonged under adverse environmental conditions. Sporulation occurs rapidly after visible symptoms occur. Spore production occurs under conditions of high humidity at night with dispersal occurring during the day. With only short periods of leaf surface wetness required for infection, rapid disease development is often observed during

September/October.

An intensive fungicidal spray programme has been recommended for control of leek rust (Long, 1992). Chemicals which currently have approval for leek rust control are fenpropimorph (Corbel), propiconazole (Tilt) and triadimefon (Bayleton). A maximum of six applications of Corbel can be applied per crop but only a maximum of three and four applications of Tilt and Bayleton respectively may be applied. Applications of fungicide at fortnightly intervals throughout the season to prevent rust affecting the stems or leaf bases is not uncommon. Fungicide spray programmes can be initiated either before disease is evident or on the appearance of symptoms in the crop. In most instances these programmes are successful but large quantities of pesticide can be needlessly applied and in some cases control is still inadequate. Information on the efficacy of more recently introduced fungicides against leek rust could provide the basis of more effective control measures in commercial crops.

1 Materials and Methods

1.1 Laboratory studies

1.1.1 Production of inoculum

Samples of infected leaves with fresh pustules and abundant sporulation were obtained from field plots of leeks (cv Winterreuzen) situated at HRI Wellesbourne. Leek leaves from the field were brushed over the leaves of 4-month-old adult plants cv Winterreuzen grown in a 70:30 mixture of Fisons F2 compost and sand in FP9 pots placed in a glasshouse. Inoculated plants were placed in a misting chamber under continuous wetness for a 48 h period. After misting plants were air dried and transferred to an isolated glasshouse at a temperature of 16 °C. Symptom development was monitored on all plants and further misting periods applied to encourage fresh symptom development as required. Inoculum produced from fresh pustules was used in all glasshouse and laboratory experiments.

1.1.2 Collection of inoculum

Inoculum was collected at regular intervals using a Copex 2D-C suction pump (Charles Austen Pumps Ltd, Byfleet, U.K.). Fresh inoculum was used in all laboratory and glasshouse experiments and was obtained by removing urediniospores from all actively producing pustules on inoculated adult plants and collecting fresh spores after a further 24 h period. Fresh rust spores were used in each laboratory and glasshouse experiment.

1.1.3 Incorporation of fungicides into tap water agar (TWA)

Each test fungicide was diluted in sterile distilled water (SDW) to give the appropriate concentration of active ingredient (a.i.) in a stock solution. The required amount of stock solution was incorporated into a 500 ml bottle of tap water agar (20 g Agar; Lucus Meyer U.K. Ltd, 1 l tap water autoclaved at 121°C for 15 minutes). Chemicals were added after the agar had been autoclaved and cooled. Each chemical was thoroughly mixed in the agar before pouring in to 9 cm diameter Petri dishes. Fresh stock solutions of each chemical were used in each experiment.

1.1.4 Inoculation of tap water agar with leek rust

Approximately 0.05 g of fresh inoculum was added to a McCartney bottle containing 10 ml SDW with 0.05% Tween 20. The spore suspension was agitated continuously to avoid sedimentation, prior to pipetting 0.1 ml on to the surface of TWA in Petri dishes. The suspension was spread evenly over the surface using a sterile spreader. Plates were sealed and randomised in a 15 °C incubator.

1.1.5 Assessment of leek rust germination on agar

Percentage germination in four replicate Petri plates at each fungicide concentration was estimated over the sampling period at 15 °C. Samples were removed from the incubator at 1, 2, 4, 6, 12 and 24 h and counted by placing a coverslip on the surface of the agar before counting 100 urediniospores at random under a microscope. Urediniospores which were not deposited on the agar in clumps were recorded in all germination counts. Germination was estimated at a magnification of x 200 and was considered to have occurred when the germ tube was distinct from the spore wall.

1.2 Glasshouse screening of fungicides

1.2.1 Plant production

Pots of leeks cv Winterreuzen (5 plants/pot), an early-season cultivar rated as susceptible to leek rust in NIAB and other classifications (Smith & Crowther, 1992) were used in all glasshouse experiments. Plants were glasshouse-raised in Hassy 308 modules with one seed per cell in a mixture of 70:30 Fisons F2 compost and sand. Seedlings were transplanted after six weeks (third leaf stage) into FP9 pots. One transplant was placed in each corner and the centre of the pot. Fertilizer regimes followed commercial practice and the seedlings were maintained in a glasshouse at approximately 18 °C until used.

1.2.2 Inoculation of plants

A leek rust spore suspensions were obtained by adding 0.2 g of freshly collected rust to 10 ml of SDW containing 0.05 % Tween 20. The resulting suspension was diluted by a factor of 10 and the concentration of urediniospores in the suspension estimated using a haemocytometer (Modified Fuch's Rosenthal, B.S. 748, Weber Scientific International, Teddington, England). The original spore suspension was diluted as appropriate using sterile distilled water to give a final dilution of 10^4 spores ml^{-1} which was applied at approximately 1 ml pot^{-1} (five seedling leeks per pot). The urediniospores suspension was applied to the leek plants with a Humbrol aerosol power unit (Philip Harris Scientific, Lichfield, England). Plants were sprayed with spore suspension in blocks of 30 pots from opposite sides. After inoculation, plants were maintained in a glasshouse compartment under continuous misting (Elkfog, ClovisLande Associates, 104 Banbridge Rd, East Peckham). Temperatures during inoculation were maintained at 16/14 °C day/night regime. Previous investigations had indicated that a 48 h misting period gave high levels leek rust infection. Plants were dried with a cool airstream using a fan (Pifco) after the 48 h misting period.

1.2.3 Application of fungicides

Fungicides were applied at concentrations above and below 1 g l^{-1} a.i.. Reduced concentrations were obtained by diluting the fungicide concentrate to obtain a suitable stock solution. The stock solution was diluted with distilled water as appropriate and applied to run off on both surfaces of 10 replicate pots of leek plants at 2, 5, 9 and 14 days post-inoculation or at 7 days pre-inoculation. Plants were incubated in a glasshouse at 18/16 °C day night temperatures after application of fungicides. Where combinations of fungicide were used in some experiments both components were mixed in equal volumes immediately before application to the plant. Fresh stock solutions of each fungicide were used in each experiment.

1.1.4 Leek rust assessment on inoculated plants

Inoculated plants were assessed for leek rust infection 21-28 days post-inoculation. The number of leek rust pustules on adaxial side of each leaf was counted for each inoculated plant in each treatment. Pustule numbers on each leaf were recounted after a 7 day period. Results were expressed in terms of the amount of infection on untreated control plants.

2 Results

2.1 Laboratory studies

2.1.1 Effect of propiconazole (Tilt) and fenpropimorph (Corbel) on leek rust germination on agar.

Approximately 95% of leek rust urediniospores germinated when placed on TWA for 1 h with no further increase in germination over a subsequent 24 h period (Figure 1 & 2). Germination on agar amended with fenpropimorph at 20 $\mu g\ g^{-1}$ declined to approximately 80% and on agar amended with 100 $\mu g\ g^{-1}$ there was a further reduction to under 20% (Figure 1). Germination was not significantly affected at concentrations of 20 $\mu g\ g^{-1}$ propiconazole. However there was approximately 80 % germination at concentrations of 40 $\mu g\ g^{-1}$ with a rapid decline to 5 % when the concentration was increased to 60 - 100 $\mu g\ g^{-1}$ (Figure 2).

2.1.2 Effect of triadimenol (Bayfidan) and fenpropimorph (Corbel) on leek rust germination on agar.

There was a similar effect on rust spores germination when concentrations of fenpropimorph at 20 - 100 $\mu g\ g^{-1}$ were applied (see section 2.1.1.) At a concentration of 100 $\mu g\ g^{-1}$ fenpropimorph reduced rust germination to under 20 % (Figure 3). However application of 20 - 60 $\mu g\ g^{-1}$ of triadimenol reduced rust spore germination from approximately 90 % in untreated samples to approximately 60 % (Figure 4) after 5 h incubation at 15°C. There was a further reduction in urediniospore germination to approximately 40 % in the presence of 100 $\mu g\ g^{-1}$ triadimenol.

2.1.3 Effect of fenpropidin (Patrol), cyproconazole (Alto), hexaconazole (Anvil), penconazole (Topas), fenpropimorph (Corbel), propiconazole (Tilt), fluzilazole (Sanction) and tebuconazole (Folicur) on leek rust germination on agar.

Fenpropidin, penconazole (Figure 5), flusilazole, tebuconazole (Figure 6) and

Figure 1. Effect of Corbel concentration on leek urediniospore germination

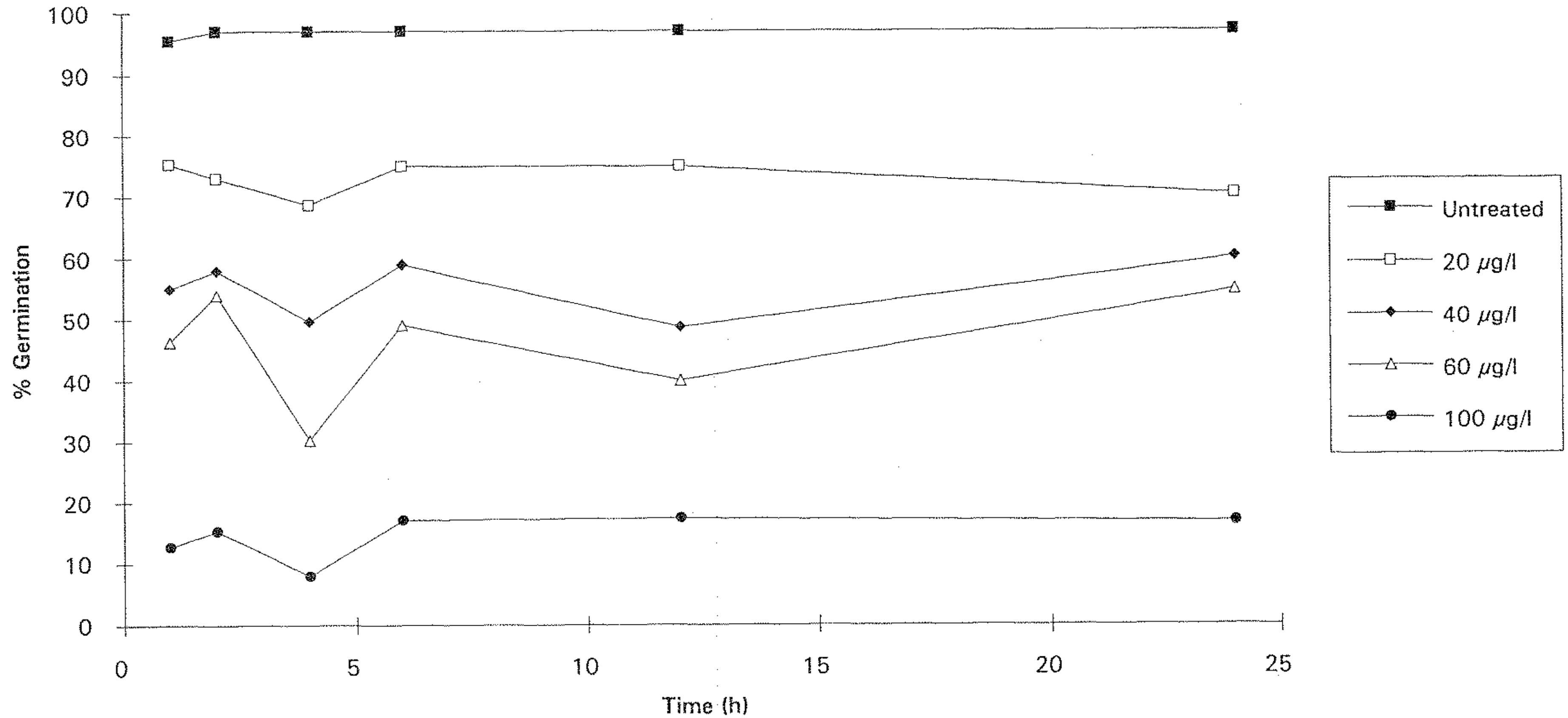


Figure 2. Effect of Tilt concentration on leek urediniospore germination

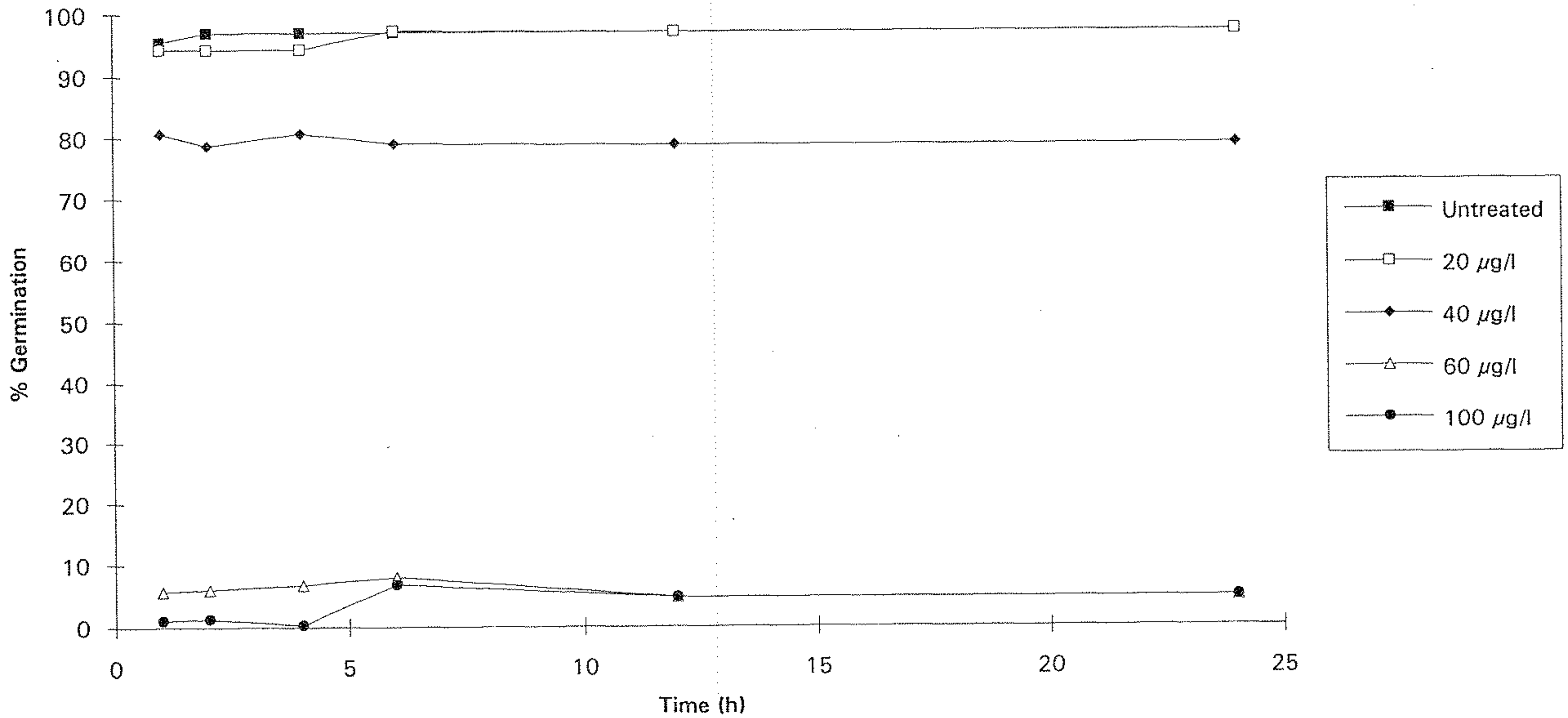


Figure 3. Effect of Corbel concentration on leek urediniospore germination

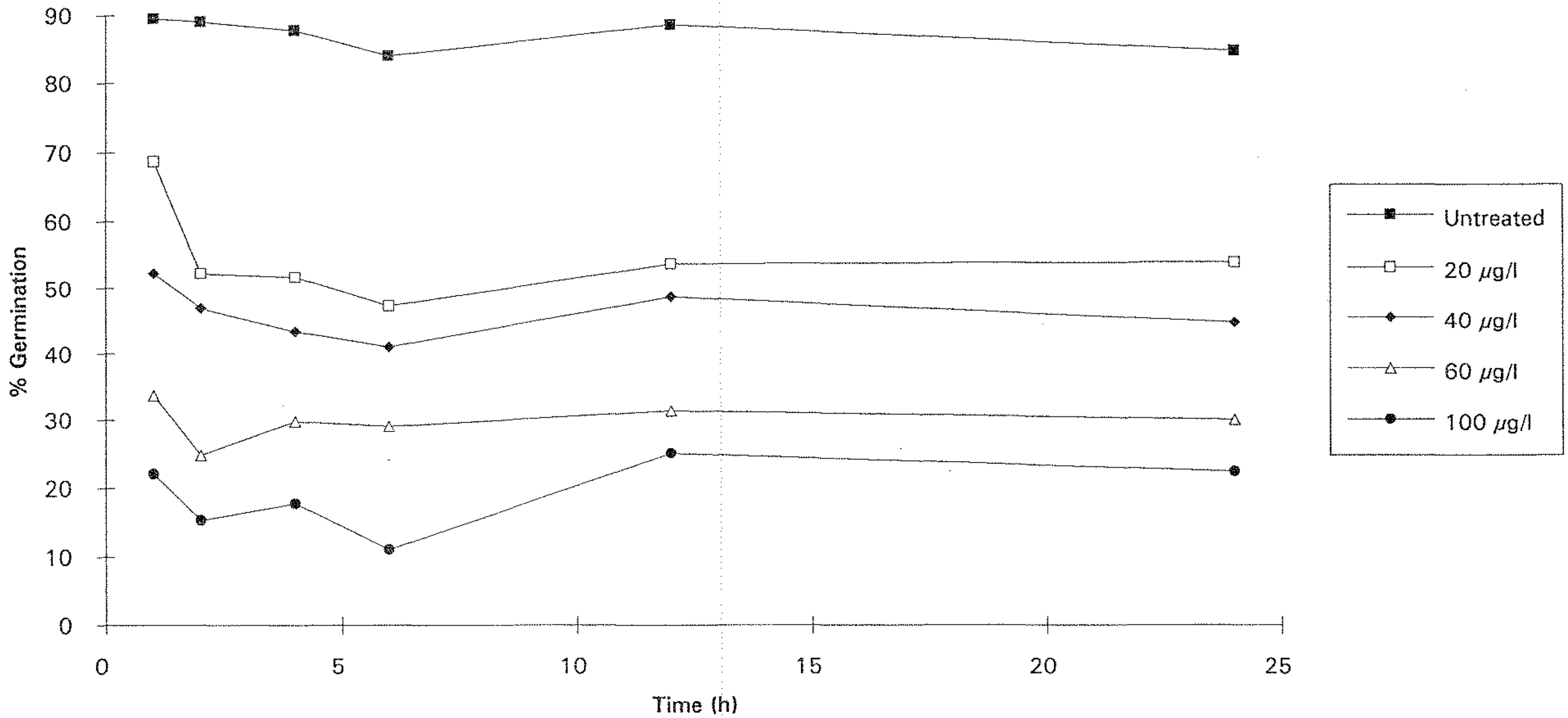


Figure 4. Effect of Bayfidan concentration on leek urediniospore germination

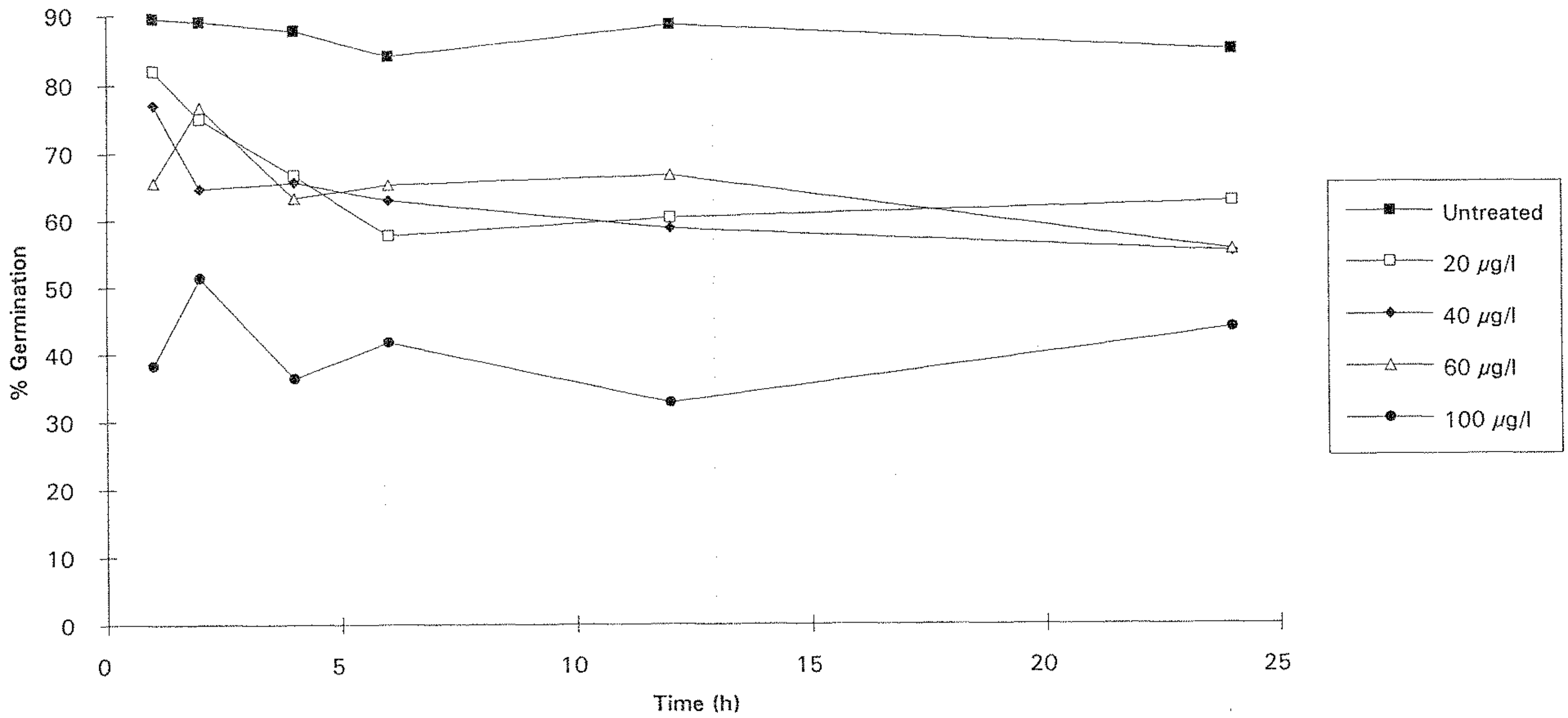


Figure 5. Effect of Patrol, Tilt, Corbel and Topas at 50 μg/l on leek urediniospore germination

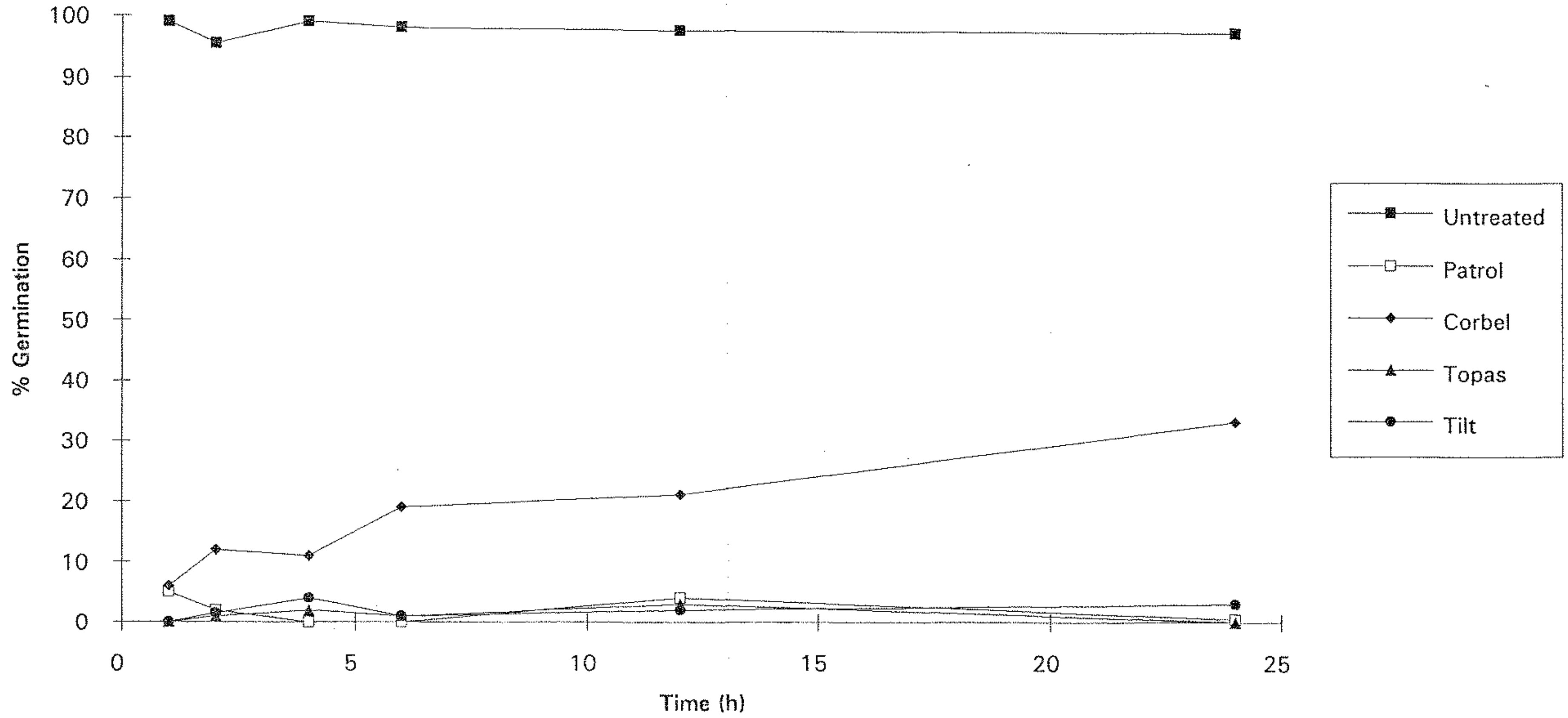
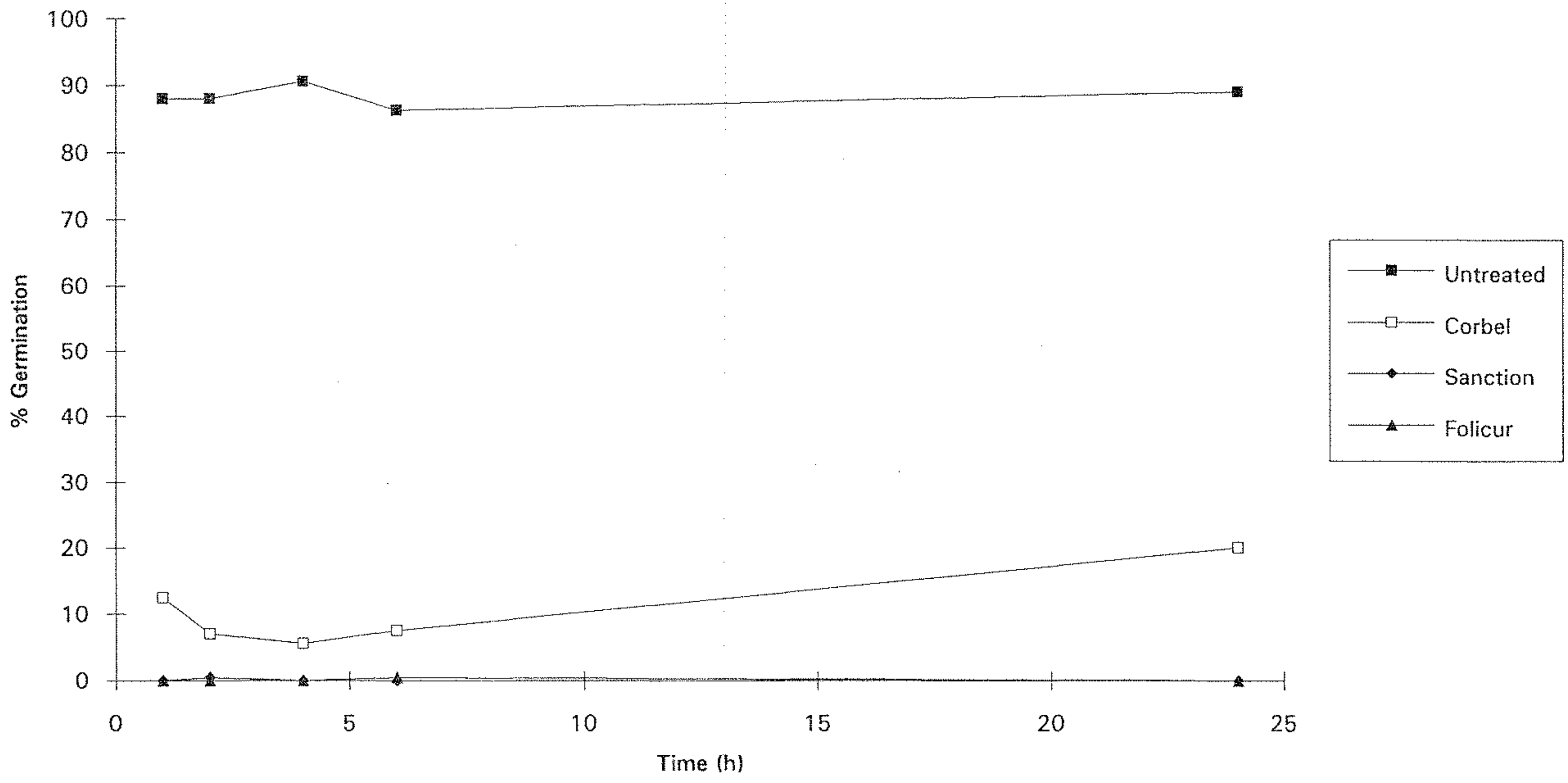


Figure 6. Effect of Sanction, Folicur and Corbel at 50 μg/l on leek urediniospore germination



hexaconazole (Figure 7) at 50 $\mu g\ g^{-1}$ in TWA reduced leek rust germination to under 5 % after 1 h incubation at 15 °C. Uredinospore germination was approximately 95 - 100 % in control samples after 1 h incubation at 15 °C in all experiments. Addition of propiconazole to the agar at 50 $\mu g\ g^{-1}$ reduced germination to under 5 % during the 24 h incubation period (Figure 5). Treatment of uredinospores with fenpropimorph at the same concentration reduced germination to approximately 40 % after 24 h in experiments comparing fenpropidin, penconazole, flusilazole and tebuconazole. However in an additional experiment where the effects of hexaconazole and cyproconazole were compared with that of fenpropimorph, germination on agar at 50$\mu g\ g^{-1}$ fenpropimorph declined to approximately 10 - 15 % (Figure 7). Application of cyproconazole in agar at 50 $\mu g\ g^{-1}$ reduced leek rust germination to approximately 80 % (Figure 7).

2.2 Glasshouse infection studies

2.2.1 Comparisons of full rates (1 g a.i. l^{-1}) with half rates and mixtures of propiconazole (Tilt), fenpropimorph (Corbel) and triadimenol (Bayleton) applied pre and post-inoculation.

Triadimenol at either 0.5 or 0.25 g l^{-1} in combination with fenpropimorph at 0.5 g l^{-1} applied seven days before inoculation of glasshouse plants with rust did not control infection in comparison to untreated control plants (Figure 8). Application of fenpropimorph at 1 g l^{-1} seven days pre-inoculation gave a 40 % reduction in rust pustules. Propiconazole and triadimenol applied separately at rates of 0.5 g l^{-1} and propiconazole at 0.25 g l^{-1} in combination with fenpropimorph at 0.5 g l^{-1} gave 60 % control of leek rust infection when applied 7 days pre-inoculation. Application of propiconazole alone at a rate of 1 g l^{-1} or in combination with fenpropimorph, at both concentrations of 0.5 g l^{-1}, reduced infection to approximately 20%.

All treatments controlled rust infection on plants when applied two days post-inoculation however fenpropimorph applied alone at 1 g l^{-1} and triadimenol at 0.25 g l^{-1}, in combination with fenpropimorph at 0.5 g l^{-1} were less effective than the other treatments when applied at either two or seven days post-inoculation. There was approximately

Figure 7. Effect of Alto, Anvil and Corbel at 50 μg/l on leek urediniospore germination

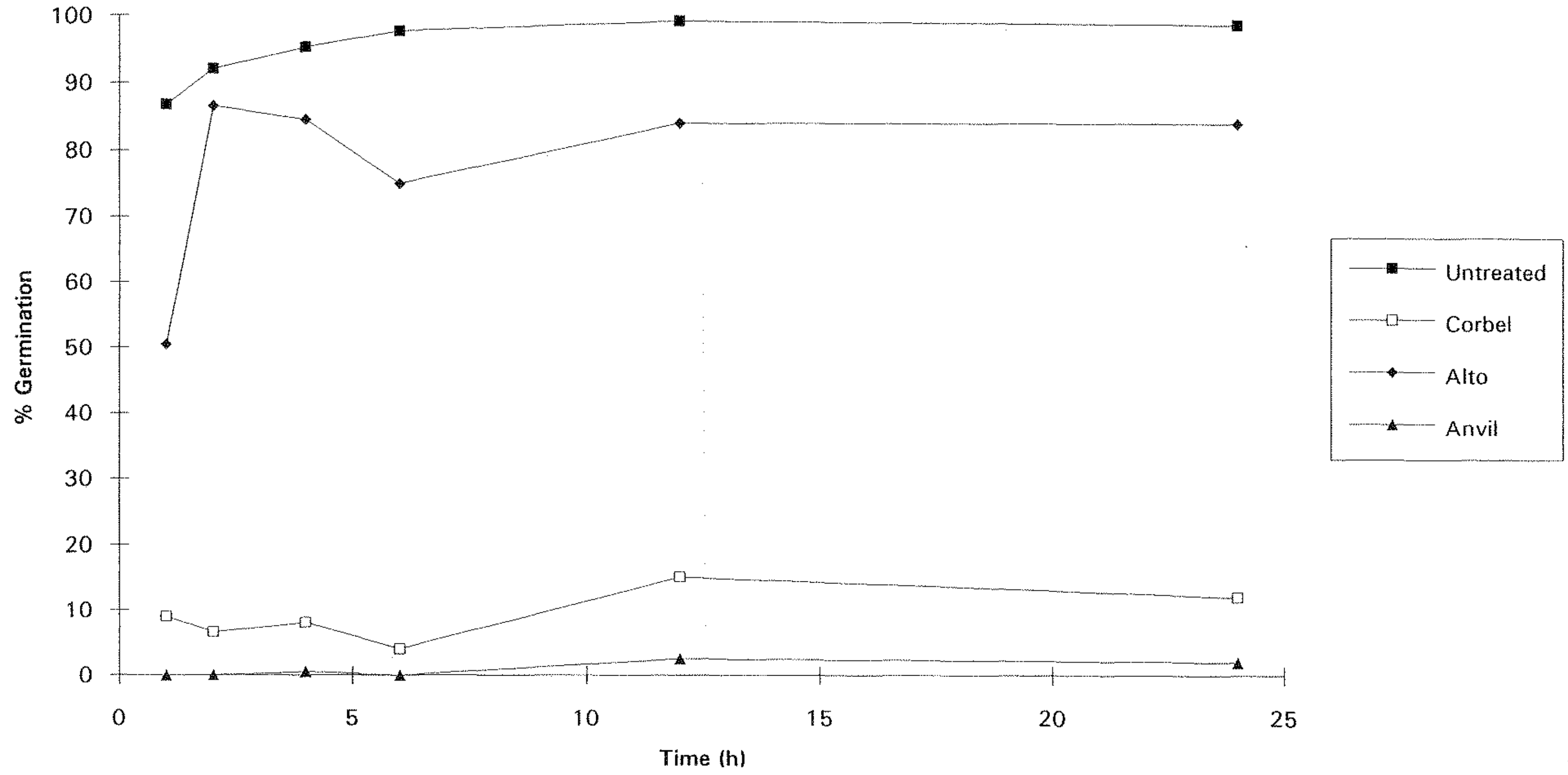
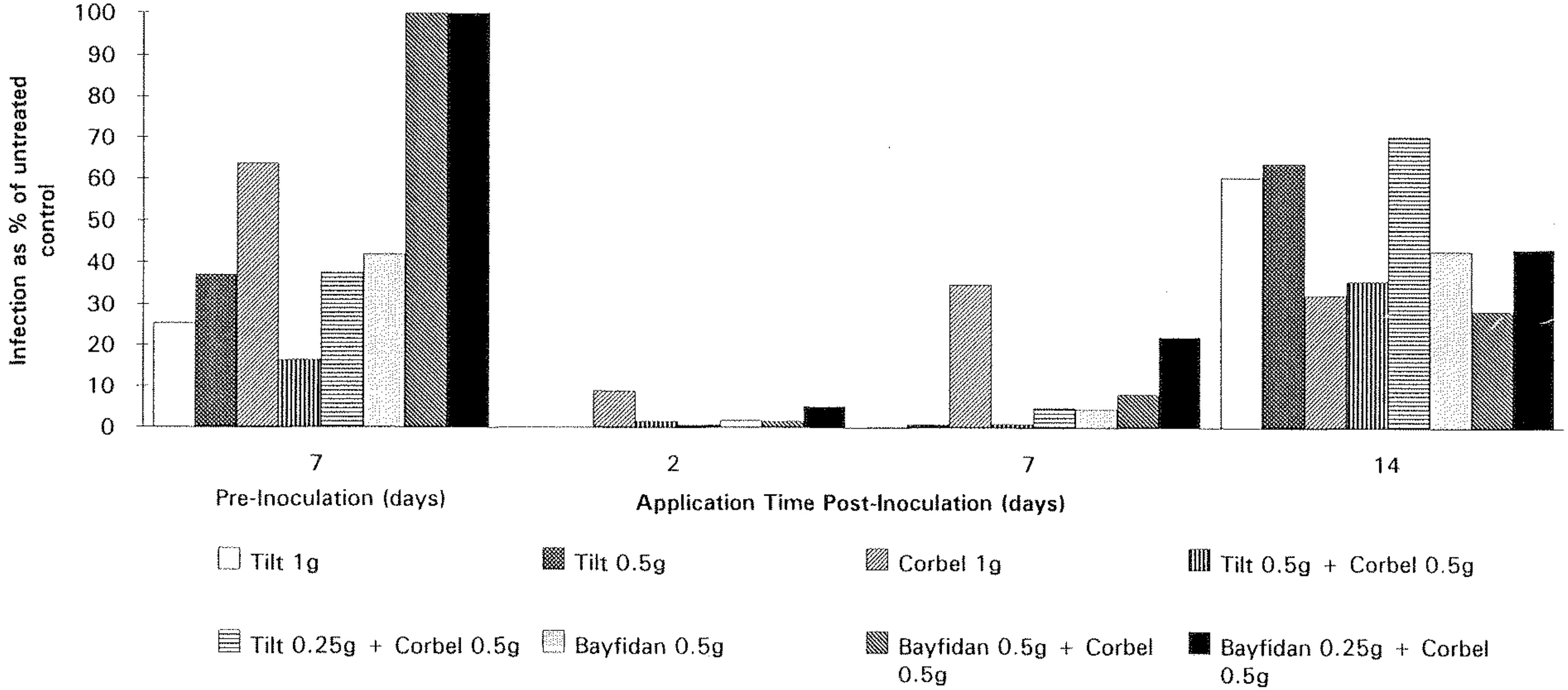


Figure 8. Effect of application of full and half rates or mixtures of Tilt, Corbel and Bayfidan on leek rust infection when applied pre and post inoculation



100% control when propiconazole was applied at 0.5g l^{-1} with or without fenpropimorph at 0.5 g l^{-1} at 7 days post-inoculation. All treatments tested were less effective in controlling rust infection when applied 14 days post-inoculation. Treatment of leeks with propiconazole at 0.5g 1^{-1} alone or in combination with fenpropimorph at 0.5 g l^{-1} were least effective in preventing rust infection.

2.2.2 Effect of fenpropidin (Patrol), hexaconazole (Anvil) and fenpropimorph (Corbel) at 1 g a.i. l^{-1} on leek rust incidence.

Fenpropidin and hexaconazole at 1g l^{-1} applied two days post-inoculation reduced infection to approximately 1 and 0 % respectively (Figure 9). There was 10 % infection on plants after treatment with fenpropimorph at nine days post-inoculation. Application of fenpropimorph 14 days post-inoculation reduced infection by 80 %. Treatment of inoculated leeks with fenpropidin was less effective in controlling infection with approximately 10 % observed when applied at 5 days post-inoculation and 20 % when applied at 9 and 14 days post-inoculation. However, hexaconazole applied up to 9 days post-inoculation controlled rust infection completely. Approximately 1 % infection occurred on inoculated leeks treated with hexaconazole 14 days post-inoculation (Figure 9).

2.2.3 Effect of penconazole (Topas), fenpropimorph (Corbel) and propiconazole (Tilt) at 1 g a.i. l^{-1} on leek rust incidence.

Application of either propiconazole or penconazole at 2, 5 and 9 days post-inoculation controlled leek rust infection completely (Figure 10). There was approximately 5 % rust infection when Corbel was applied up to 14 days post-inoculation. Tilt and Topas were less effective when applied at 14 days post-inoculation with approximately 30 % infection.

Figure 9. Effect of application of Anvil, Patrol and Corbel at 1g a.i l^{-1} on leek rust infection

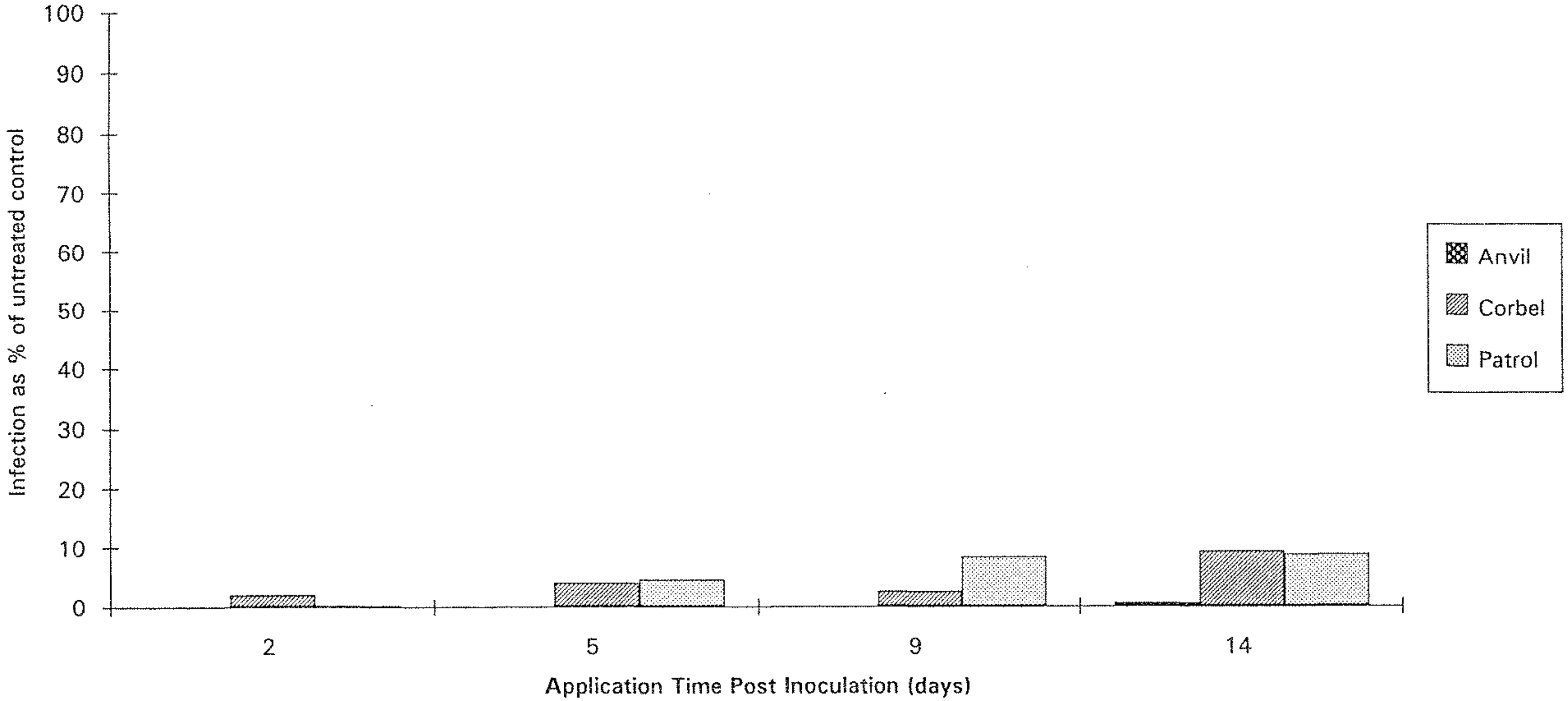
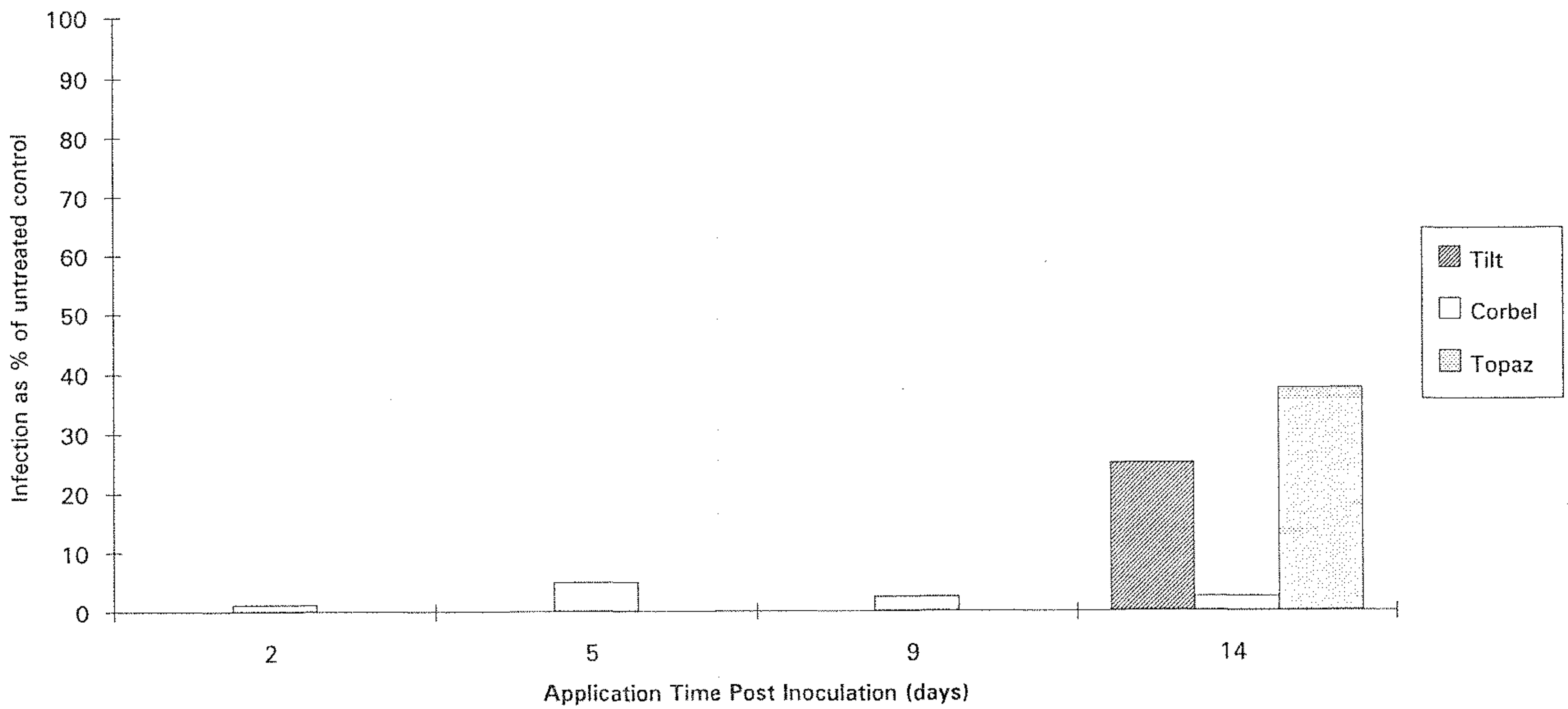


Figure 10. Effect of Tilt, Corbel and Topaz at 1g a.i l^{-1} on leek rust infection



2.2.4 Effect of tebuconazole (Folicur), flusilazole (Sanction) and propiconazole (Tilt) at 1 g a.i. l^{-1} on leek rust incidence.

Tebuconazole and flusilazole applied at 2, 5 and 9 days post-inoculation reduced rust infection to 0 % (Figure 11). Propiconazole was less effective in comparison to either tebuconazole or flusilazole with approximately 10 % infection observed when propiconazole was applied at the same time intervals post-inoculation. Applying propiconzole or flusilazole at 1 g l^{-1} 14 days post-inoculation was not effective in controlling rust infection and reduced it by only 50 %. In contrast tebuconazole was more effective than either propiconazole or flusilazole when applied at 14 days post-inoculation and reduced rust infection to approximately 20 % (Figure 11).

2.2.5 Effect of concentration of active ingredient of fenpropimorph (Corbel) applied post-inoculation on leek rust incidence.

Application of fenpropimorph at concentrations of 1.0, 1.5 and 2.0 g a.i. l^{-1} reduced rust infection to approximately 10 % when applied at 2 and 5 days post-inoculation (Figure 12). Application of fenpropimorph at 0.5 g a.i. l^{-1} was less effective when applied over the same time intervals with 20 - 25 % rust infection observed. Control of infection was most effective when 2.0 g l^{-1} fenpropimorph was applied 2 days after inoculation. Rust infection increased to approximately 15 % in those treatments where 1.0, 1.5 and 2.0 g a.i. l^{-1} fenpropimorph was applied nine days after inoculation. Approximately 20 % infection was observed on treatments where fenpropimorph was applied at 0.5 g a.i l^{-1} nine days after inoculation. Treatment of inoculated plants with 0.5 g a.i. l^{-1} fenpropimorph at increasing times post-inoculation was less effective with increasing levels of infection of approximately 50 % observed. Concentrations of fenpropimorph above 0.5 g a.i. l^{-1} were less effective in controlling rust infection when applied at 14 days post-inoculation as rust infection increased to approximately 25 % in treatments given 1.0 and 2.0 g a.i. l^{-1}.

Figure 11. Effect of application of Tilt, Folicur and Sanction at 1g a.i^{-1} on leek rust infection

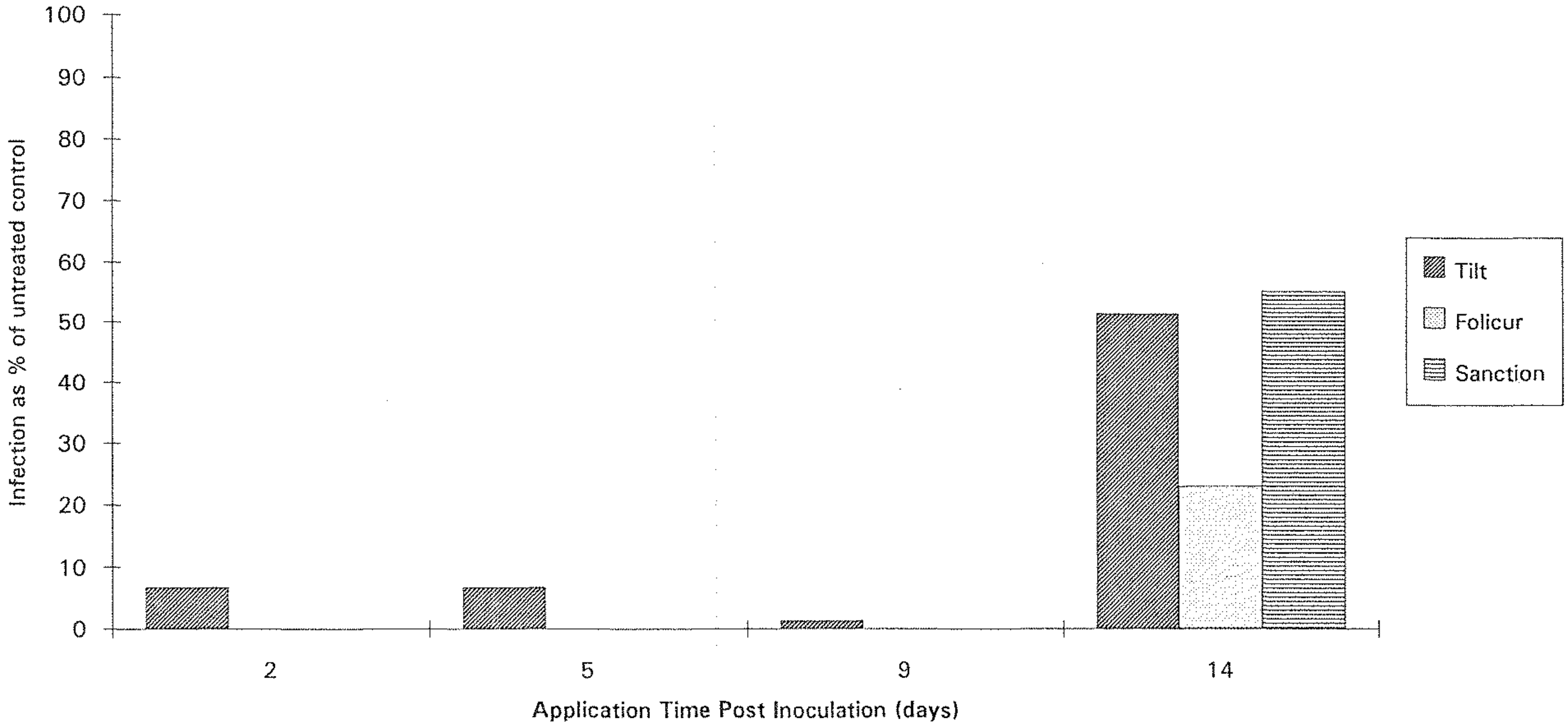
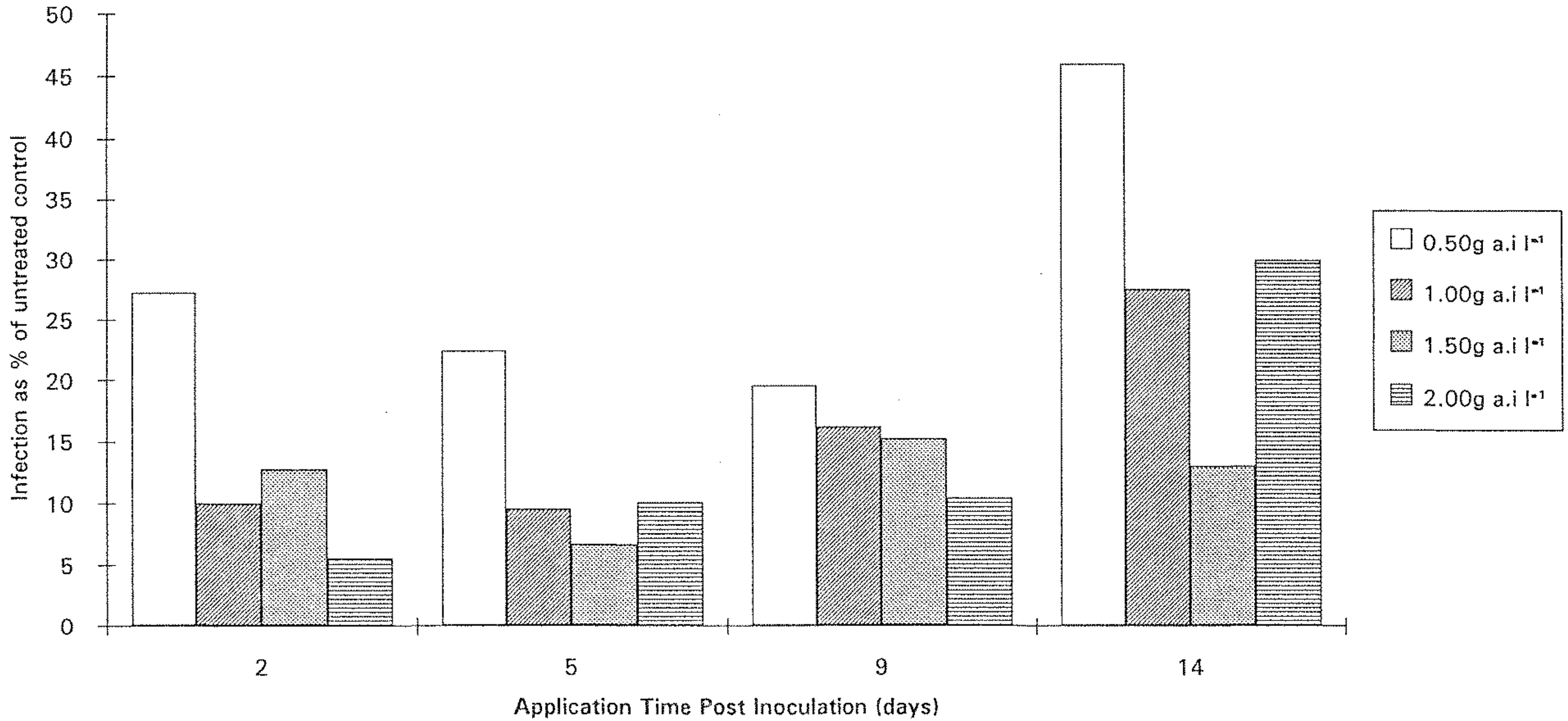


Figure 12. Effect of concentration of Corbel on leek rust inoculation



2.2.6 Effect of concentration of active ingredient of hexaconzazole (Anvil) applied post-inoculation on leek rust incidence.

Application of hexaconazole at 0.25, 0.5, 0.75 and 1 g a.i. l^{-1} at 2, 5, and 9 days post-inoculation reduced rust infection to trace levels (Figure 13). No infection was observed on plants where these treatments were applied 9 days after inoculation regardless of concentration. There was approximately 10 % rust infection observed on plants where 0.25 g l^{-1} hexaconazole had been applied 14 days post-inoculation. However, there was approximately 50 % infection when concentrations of 0.5g l^{-1} hexaconazole were applied 14 days after inoculation.

2.2.7 Effect of concentration of active ingredient of tebuconazole (Folicur), applied post-inoculation on leek rust incidence.

Rust infection was reduced to zero when tebuconazole was applied at 0.25, 0.5, 0.75 and 1 g a.i. l^{-1} at 2 days post-inoculation (Figure 14). Tebuconazole applied at the same concentrations 5 and 9 days post-inoculation reduced infection to approximately 2 - 3 %. However when tebuconazole was applied 14 days post-inoculation at all concentrations tested there was approximately 20 - 30 % rust infection.

Figure 13. Effect of concentration of Anvil on leek rust infection

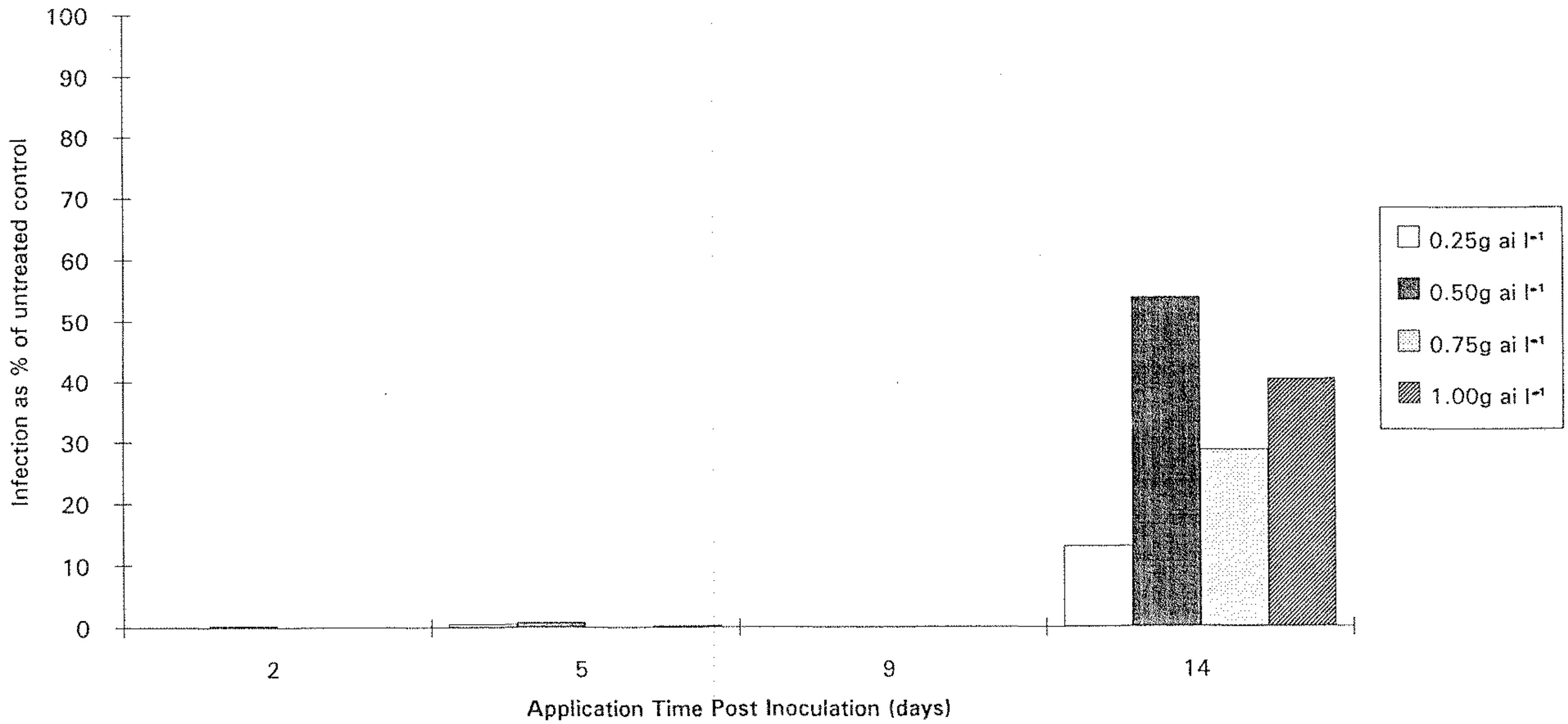


Figure 14. Effect of concentration of Folicur on leek rust infection

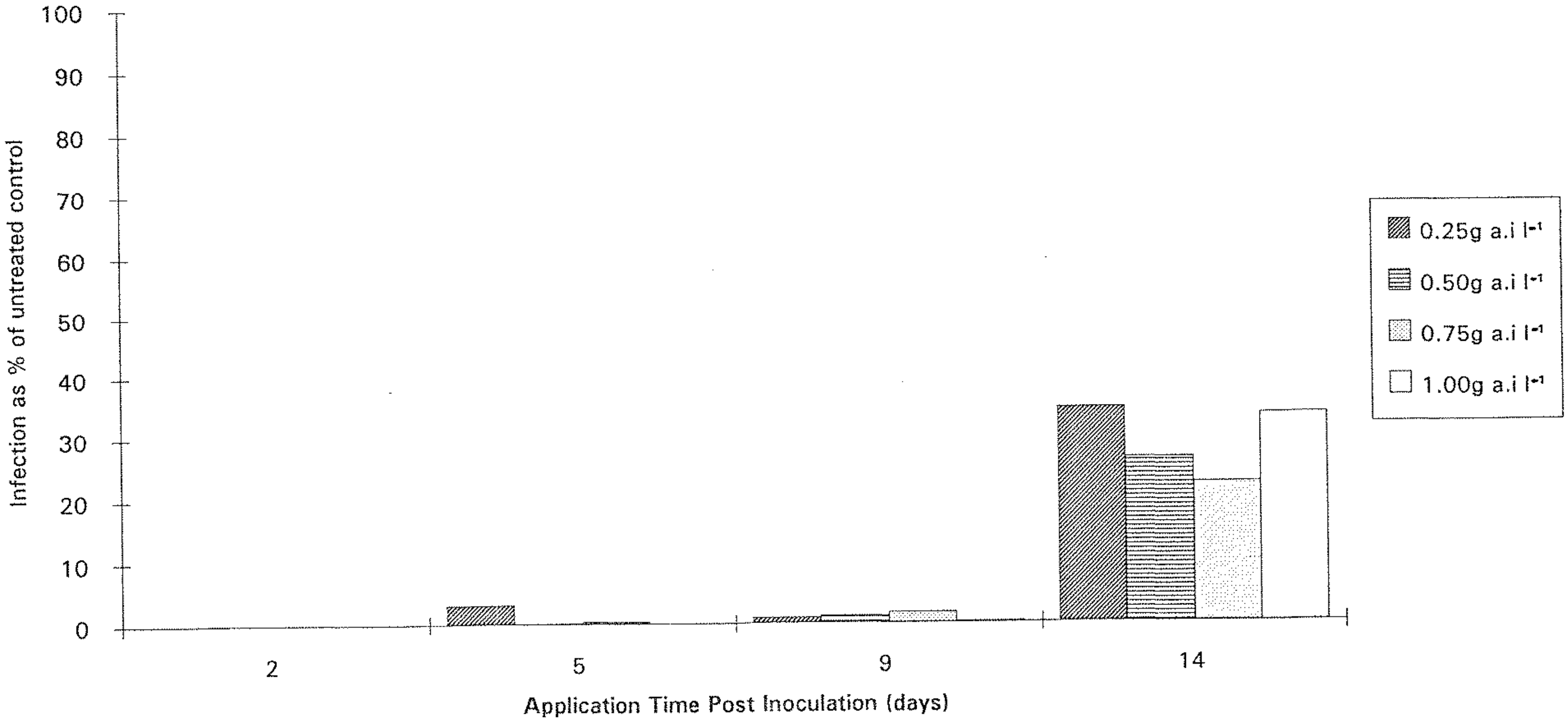


Table 1 Summary of the effect of fungicides on urediniospore germination (24 h post-application) and rust incidence applied (7 and 12 days post-infection)*.

APPLICATION	*in vitro* 50μg l^{-1}	*in vivo* 1g l^{-1}	*in vivo* 1g l^{-1}
RESPONSE	% Germination	% Severity	% Severity
FUNGICIDE/TIME	24 h	7 days	12 days
Tilt	3	0-2	30-65
Topas	0	0	40
Anvil	2	0	1-45
Folicur	0	0	25-35
Sanction	0	0	60
Patrol	1	9	10
Bayfidan	56	NT	NT
Alto	86	NT	NT
Corbel	30	2-17	5-35

NT - Not tested at this concentration.

* - Infection is assumed to have occurred 48 h post-inoculation.

Discussion

Laboratory and glasshouse experiments compared fungicides known to activity against other species of rust with the activity of fungicides which have approval for leek rust control. High eradicant activity was demonstrated for several fungicides. There was significant eradicant activity up to 9 days post-inoculation with applications of Folicur, Anvil, Sanction and Topaz compared to the approved fungicides, Corbel and Tilt. There was some evidence that when Anvil, Folicur and Sanction were applied 14 days post-inoculation the rate of symptom development was reduced although this could not be accurately assessed under glasshouse conditions. Significant reductions in rust infection in combination with possible effects on latent or infectious period following application of these chemicals would be predicted to have detrimental effects on leek rust development within commercial crops. Furthermore, because these chemicals have strong eradicant activity when applied up to seven days after infection has occurred, the difficulties in application of fungicides to the crop at certain times of the season may also be reduced. Further field evaluation of the above chemicals is however necessary to ensure that the eradicant activity observed under glasshouse conditions is maintained in the field.

The mode of action of all fungicides tested in this study is the inhibition of ergosterol biosynthesis. However, several types of ergosterol biosynthesis inhibiting fungicides (EBI) have been developed. Corbel, for example, belongs to the morpholine grouping of EBI fungicides. However most of the new products tested belong to the triazole of DMI (demethylation inhibitors) group of fungicides all of which block ergosterol biosynthesis at the same stage. Within the triazole grouping considerable variation exists in the structure of the basic dioxoline ring components of the compound. Compounds where the dioxoline ring has been replaced by other five member structures have been found to be particularly active against cereal rusts (Worthington, 1984). It would be interesting to compare the effective products in this study with respect to their dioxoline ring structure.

Mixtures of fungicides with different activities may also vary in their activity and confirm some advantage in comparison to applications of one of the components of the mixture alone. The results of the present study appear to support this hypothesis where to some extent mixtures of Corbel and Tilt (at low concentrations) were more effect than either component by itself. However further studies would be required to confirm this finding.

The results show that mixtures of chemicals had some effect in controlling leek rust infection post-inoculation but were less effective when applied protectively. Most combinations tested were effective in reducing leek rust infection when applied 7 days post-inoculation. Combinations of Tilt and Corbel each at 0.5 g l^{-1} were particularly effective in this respect in comparison to Corbel at 1 g l^{-1}. However they were not as effective in comparison to Tilt applied alone at either 0.5 or 1.0 g l^{-1}. Most of the effectiveness of these mixtures would appear to result from the application of Tilt as a component part. Application of Corbel in combination with Bayfidan appeared similar to the effects of mixtures of Tilt and Corbel. However, Bayfidan was less effective at the concentrations tested in combination with Corbel compared to mixtures of Tilt and Corbel at the same concentrations. Bayfidan appeared to have little protective effect in controlling leek rust infection, a result which is reflected in its relative lack of effect on urediniospore germination even at relatively high concentrations of active ingredient (100 $\mu g\ l^{-1}$).

Most chemicals tested with the exception of Alto (cyproconazole) had an effect on leek urediniospore germination at concentrations of 50 $\mu g\ l^{-1}$ which indicates that these chemicals probably would give good protective control of leek rust infection. Tilt appeared to have stronger protective action against leek rust infection than Corbel which may explain its higher observed level of control in the field. Application of Tilt at concentrations over 40 $\mu g\ l^{-1}$ reduced leek rust urediniospore germination to under 10 %.

Reduced dosages of both Folicur and Anvil were effective in controlling leek rust infection to neglible levels when applied at 9 days post-inoculation. However there was relatively poor control of leek rust infection when Corbel was applied at concentrations above and below 1 g l^{-1} a.i.. Applying Corbel at half rates gave consistently reduced control of infection in comparison to higher rates of application. The results indicate that there is considerable potential for controlling leek rust with both Anvil and Folicur using half rates which appeared effective when applied a considerable time after infection had occurred. The effectiveness of reduced dosages suggest that applying mixtures of these effective chemicals in this way may be a particularly effective strategy in controlling leek rust in the field.

Both Topas and Patrol were phytotoxic when applied in the glasshouse to young leek plants. However no other chemical tested was observed to give phytoxicity at the concentrations tested. Chemicals were applied under glasshouse conditions only and not under the full range of environmental conditions experienced in the field. It will therefore be important to test promising chemicals further under field conditions to observe the degree of control and the possible occurrence of phytotoxicity.

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