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THE USE OF METALAXYL FOR THE CONTROL OF DOWNY MILDEW DISEASES

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Summary The use of metalaxyl for the control of potato blight *(Phytophthora infestans)*, hop downy mildew *(Pseudoperonospora humuli)*, brassica downy mildew *(Peronospora parasitica)* and other downy mildew diseases is discussed.

In potatoes, trial results showing superior blight control relative to the standard by metalaxyl with or without mancozeb, are presented. Fewer applications were required and both the rainfastness of the sprays and the excellent tuber blight control are highlighted.

In hop and brassica trials, virtually complete disease control was given by single soil-applied treatments and surveys show that this property has already had a significant impact on hop downy mildew control in England.

Other examples of radical changes in disease control practice from both the U.K. and abroad, which are possible with metalaxyl, are mentioned.

Résumé L'utilisation de metalaxyl pour la lutte contre le mildiou de la pomme de terre *(Phytophthora infestans)*, mildiou du houblon *(Pseudoperonospora humuli)*, mildiou du brassica *(Peronospora parasitica)* et d'autres mildious est discutée.

Les résultants d'essais sur pommes de terre présentés, montrent l'activite supérieure de metalaxyl, associé ou non avec Mancozeb, par rapport au standard. Le nombre d'applications peut être réduit. L'absence totale du lessivage par la pluie et l'excellente protection des tubercules ont été mis en évidence.

Dans des essais sur houblon et brassica, un contrôle total du mildiou a été obtenu avec un unique traitement au sol. Des observations ont montré que cette propriété a déjà eu un impact significatif sur la lutte contre le mildiou du houblon en Angleterre.

D'autres exemples de changements radicaux obtenus dans la lutte des maladies grâce à metalaxyl, tant en Angleterre qu'à l'étranger, ont été rapportés.

INTRODUCTION

The systemic fungicide metalaxyl was first announced in 1977 (Schwinn et al. 1977);both its general and biological properties were discussed at the 1977 Brighton Conference (Urech et al. 1977). Since then, extensive laboratory and field testing has been conducted and the fungicide has been commercially introduced in several countries for the control of pathogens belonging to the order Peronosporales; this includes both airborne pathogens e.g. late blight of potatoes *(Phytophthora infestans)*, vine downy mildew *(Plasmopara viticola)* and soil-borne pathogens e.g. black shank of tobacco *(Phytophthora nicotianae* var. *nicotianae)* and damping-off caused by *Pythium spp.*

The object of this paper is to give examples of such uses especially from the United Kingdom and to highlight those uses which allow a modification of traditional disease control or husbandry practices.

MATERIALS AND METHODS

Metalaxyl, code numbered CGA 48988, was used either as a 25% or 50% wettable powder formulation (RIDOMIL ®), or in mixture with mancozeb (FUBOL ®) as a 10 + 48% w.p. of metalaxyl and mancozeb respectively.

Potato trials were of randomised block design with four replications and a plot size of either 2 assessable rows x 8 metres or 3 assessable rows x 7 metres (ADAS Trawsgoed). Sprays were applied by precision plot sprayer in 200 to 250 l/ha water. Tuber yields were estimated from hand dug samples of at least 10.7 metres row per plot or 10 x 6 metre rows in the case of the grower applied trial 071 78. Foliar blight was assessed according to ADAS key number 2.1.1 in all cases. Tuber blight was assessed 3 to 8 weeks after harvesting following storage in dry conditions.

Hop trials were comparisons of 2 or 3 treatments replicated twice; rootstock drenches and later foliar sprays being applied by grower's equipment onto plots containing 270 to 1050 assessable rootstocks. This allows an adequate sample for yield assessment of hop cones by conventional commercial harvesting techniques. Routine sprays of standard copper or dithiocarbamate fungicides were applied from late April/early May as was the standard practice. Metalaxyl sprays were applied from 10-12 weeks after a single soil-appled drench in early April. Assessment of foliar infection was on a simple presence or absence basis.

The cauliflower downy mildew trial (ADAS Evesham Sub-Centre) was of a 4 replicate randomised block design with a plot size of 1.0 x 1.0 metres. Assessment of foliar disease and quality at harvest were made by ADAS plant pathology staff.

RESULTS

Potatoes

Trials with metalaxyl in the U.K. against late blight of potatoes have been conducted over 4 years. These were initially with metalaxyl alone, but as a metalaxyl + mancozeb mixture was being tested in Continental Europe and some southern hemisphere countries with the aim of ensuring control of early blight *(Alternaria solani)*, this mixture was also included in the U.K. trials on a speculative basis. It became apparent from an early stage in the U.K. development programme that the addition of mancozeb to metalaxyl frequently gave a non-significant but superior control of foliar blight. The result overleaf was from a trial in Somerset in 1977; one of ten which lead to the above conclusion.

By September 20th foliar blight had reached 12% in the standard mancozeb plots and at this stage the crop was desiccated prior to harvesting 21 days later. The foliar blight control given by metalaxyl alone and in mixture was superior to mancozeb, even with a reduction in spray applications from 6 to 4; a basic 14-day spray programme being followed for mancozeb and a 21-day programme for the metalaxyl treatments during periods of low to moderate blight risk. Tuber blight levels were low, but it was noticeable on this and other sites that there was a small but consistent level of attack in mancozeb treated plots but a negligible attack in metalaxyl treated plots.

Table 1

Control of late blight on potatoes - trial 066 77 Somerset

Treatment	Kg ai/ha	No. of sprays applied	% foliar blight September	% tuber blight by weight	Ware yield t/ha
mancozeb	1.36	6	12	0.93	45.8
metalaxyl + mancozeb	0.15 + 0.68	4	8	0	45.5
metalaxyl	0.2* + 0.3	2 + 2	10	0.08	43.3
SE treatment means (P = 0.05)				-	2.49

*dose increased from 0.2 to 0.3 at end of August

Similar results were obtained in 1978 when foliar blight attack was generally earlier than in 1977, but progressed more slowly throughout August and September giving an unusual opportunity to compare treatments over a 5 to 8 week period. Such a result for a small plot trial in Cambridge is given in Figure 1.

The metalaxyl-based products again gave superior foliar blight control relative to the standard and on a reduced spray programme. The progress curves from the various treatments show how well the metalaxyl-based product controlled the infections in August. However, from the second week in September, foliar blight levels on plots treated with metalaxyl alone increased more quickly than where the metalaxyl + mancozeb mixture was used.

The same pattern of foliar blight attack can be seen from the results of the ADAS Trawsgoed trial, presented in Figure 2. The degree of attack was much more serious than in the Cambridge trial, foliar blight on unsprayed plots reaching 75% leaf area destroyed by 30th August after being first recorded on 25th July within the trial area. All fungicides gave virtually complete disease control until early September, mancozeb sprays being applied from 18th July and metalaxyl-based sprays from 4th August on the dates shown. However, it was again noticeable that from mid September onwards, foliar blight levels increased more rapidly on plots treated with metalaxyl alone than those treated with metalaxyl + mancozeb. We think that this fall-off in foliar protection by metalaxyl alone may be caused by decreased uptake and internal transport by the senescing plant; a property so far only relevant to potato production in the U.K. as the crop is not grown for such a protracted period in the other countries in which metalaxyl is used. In any case the effect may only be of cosmetic value as is seen from the tuber blight control data in both Figure 1 and 2.

In the Cambridge trial, 2.2% by weight of untreated tubers were blighted after 8 weeks storage. 0.6% of the mancozeb treated crop was infected, 0% following metalaxyl treatment and 0.17% following metalaxyl + mancozeb. In the Trawsgoed trial where 180 mm rainfall was recorded during the duration of the blight epidemic, the tuber blight attack was more severe. Tubers had 5.2% blight in untreated plots, with virtually no improvement following mancozeb treatment at 5.0% infection. In contrast, plots treated with metalaxyl and metalaxyl + mancozeb treatments had 0.5% and 1.0% tubers infected respectively. (Statistically significant at P = 0.05). Results from both sites show the big improvement in tuber blight control given by metalaxyl alone or in mixture relative to mancozeb; they also demonstrate that the slightly poorer foliar blight control given by metalaxyl alone relative to the mixture was of no practical significance.

An increase in yield of saleable tubers resulted from the use of metalaxyl + mancozeb in both the above trials. The results are given in Table 2:-

Table 2

Yield of saleable tubers - trial 061 78, Cambridge and ADAS Trawsgoed

Treatment	Kg ai/ha	No. of sprays applied	Yield of ware tubers at harvest in t/ha 061 78	ADAS Trawsgoed
untreated	-	-	41.7	42.9
mancozeb	1.36	8 or 6	44.8	67.3
metalaxyl + mancozeb	0.15 + 0.72	6 or 5	46.6	77.2
metalaxyl	0.25	6 or 5	44.8	73.2
SE treatment means (P = 0.05)			±2.29	±4.58

Such yield increases attributable to the use of metalaxyl frequently occurred in both small-plot and grower-application trials where single strip comparisons were made. In the latter, such differences were frequently due to delayed haulm desiccation relative to the standard treated plot, or reduced mechanical damage due to fewer application numbers. Such an example is 071 78, a trial on Pentland Dell at Saltash, Cornwall, where the local practice is to desiccate at just over 1% foliar

Figure 1
Control of late blight on potatoes—trial 061, 78, Cambridge
Variety: King Edward

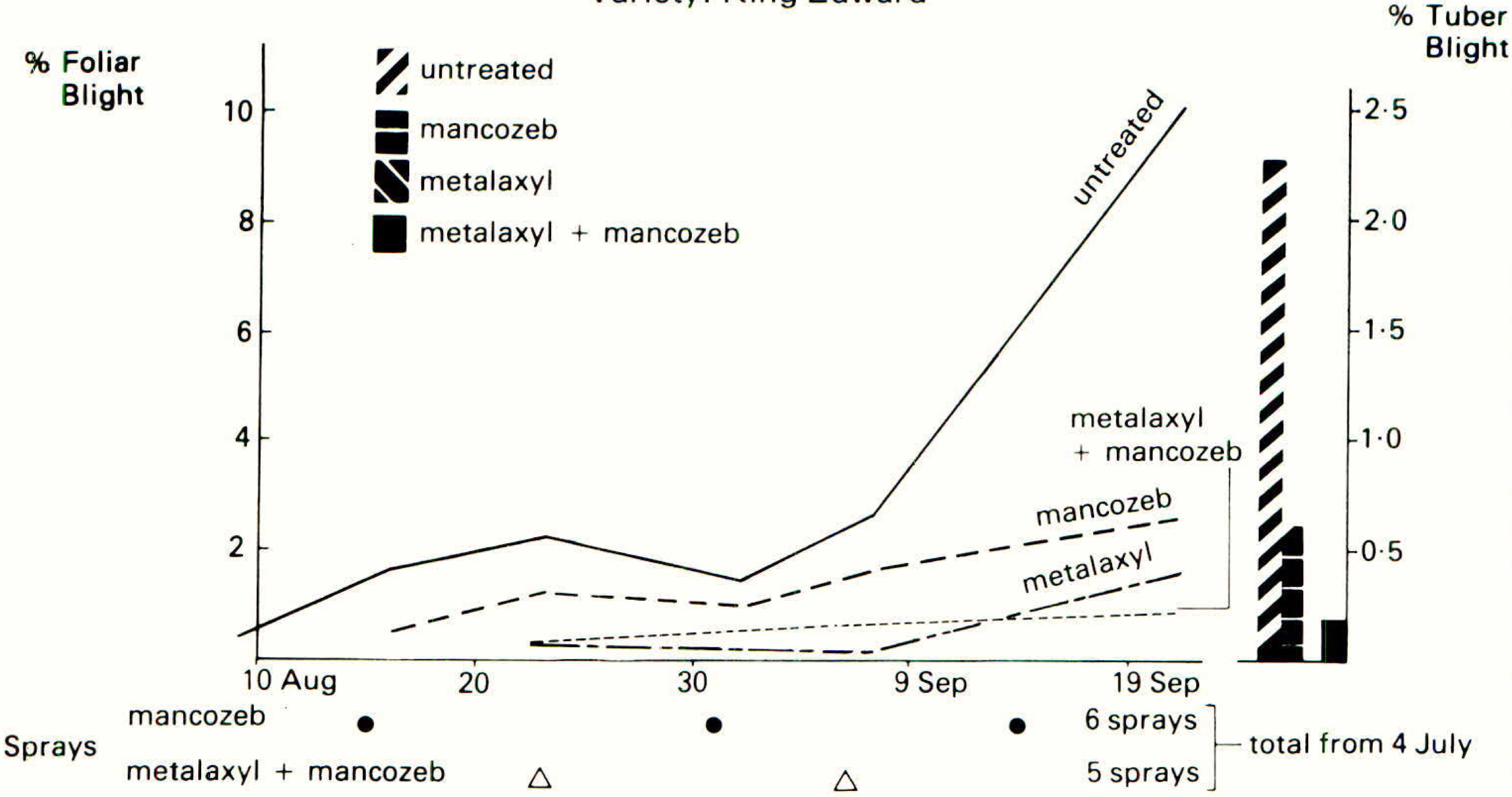
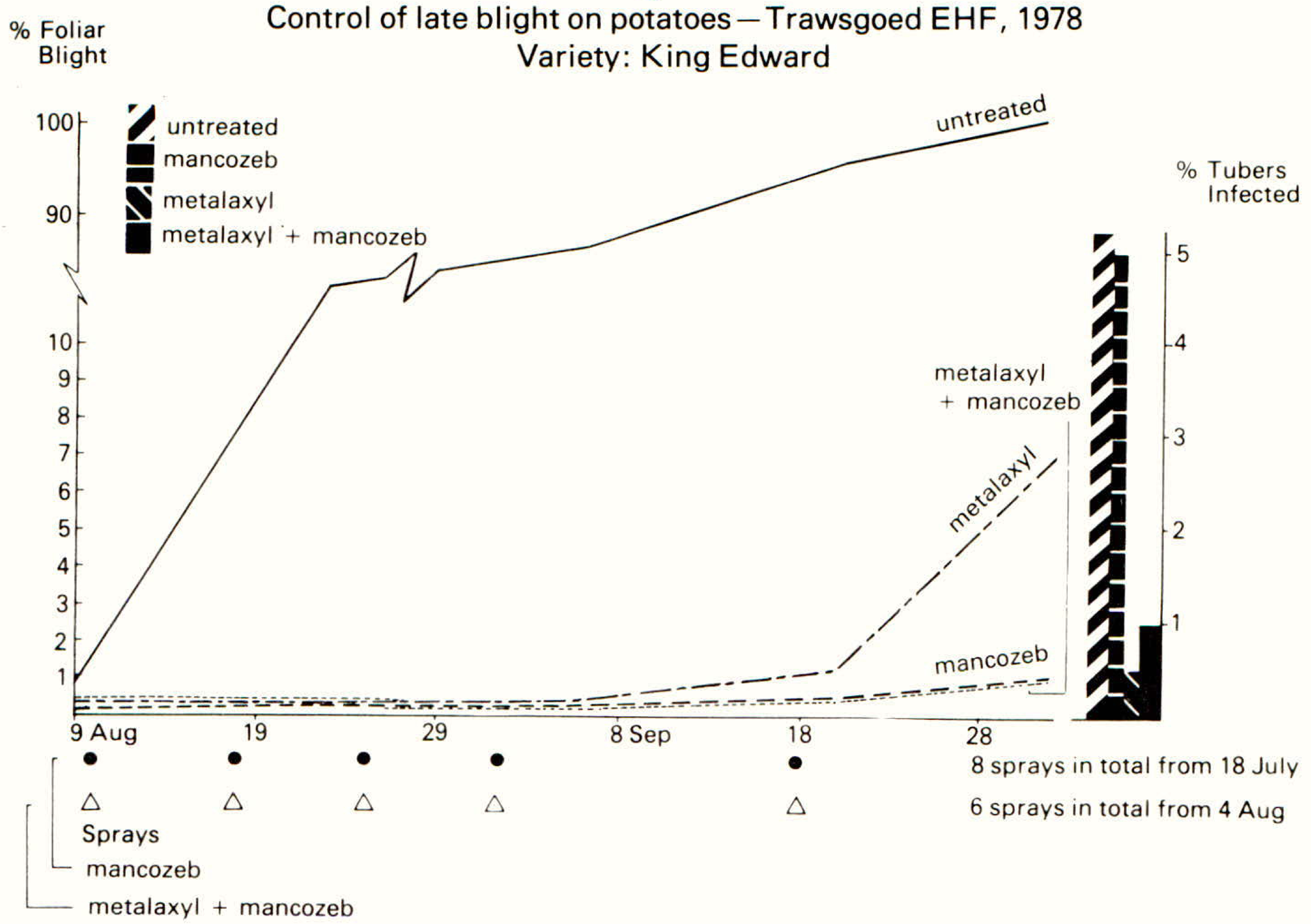


Figure 2
Control of late blight on potatoes – Trawsgoed EHF, 1978
Variety: King Edward



Results of unpublished work by courtesy of ADAS Plant Pathology Department, Trawsgoed

blight. Following sprays at 7 day (mancozeb) or 14 day (metalaxyl + mancozeb) intervals, crop growth continued for an extra 5 weeks during September and early October in the metalaxyl + mancozeb plot. The result is shown in Table 3.

Table 3

Foliar blight control and ware yield - trial 071 78, Saltash

Treatment	Kg ai/ha	No. of sprays applied	Date of desiccation at c. 1% blight	Yield of ware tuber t/ha
mancozeb	1.36	11*	31 August	62.6
metalaxyl + mancozeb	0.15 + 0.72	8**	7 October	72.6

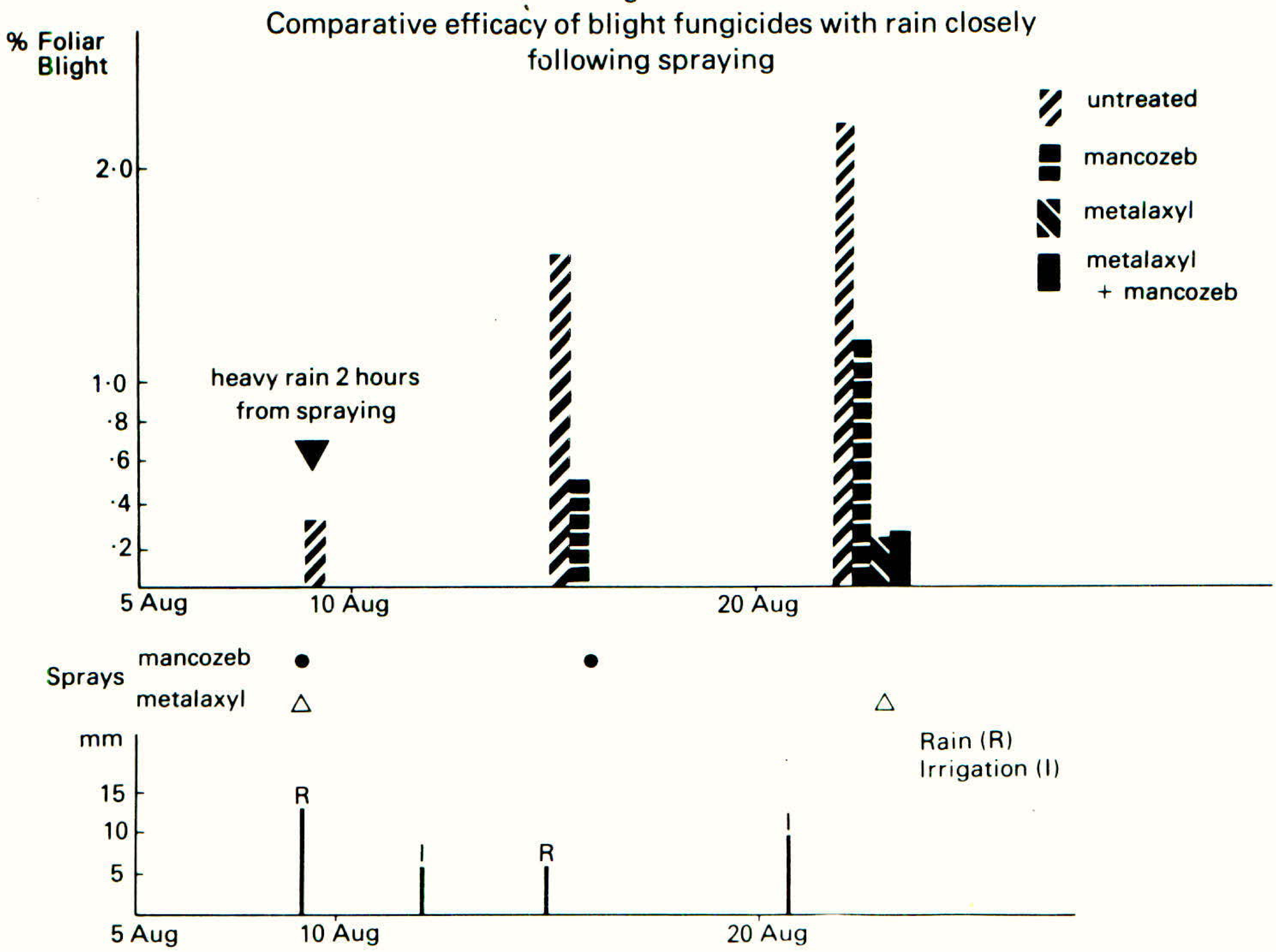
* last spray 29th August, crop desiccated 31st August

** last spray 25th September

This result may be exceptional in that foliar blight was less severe than normal for Cornwall in 1979. However, it demonstrates the real possibility that this new fungicide will allow a substantially longer period of crop growth in high blight risk situations with little danger from severe tuber blight attack. Where 8 or more sprays are routinely applied, it is reasonable to assume that by reducing spray numbers to three quarters or half those of the standard protective fungicides, an increase in saleable yield will result through reduced wheeling damage.

A further property of metalaxyl which greatly enhances its acceptability as a potato fungicide is its rapid penetration into the leaf, especially under conditions of high humidity. Laboratory studies with metalaxyl and other analogues from the acylalanine group have shown that under such conditions penetration of the leaf is complete in a matter of hours (Staub et al. 1978). This property was confirmed in the field in 1978 when heavy rain fell within 2 hours of spraying. The result is illustrated in Figure 3:-

Figure 3
Comparative efficacy of blight fungicides with rain closely following spraying



Although the manoczeb treatment was repeated 7 days after the previous application and subsequent rainfall, there was a rapid increase in foliar blight on both untreated and mancozeb treated plots; a result largely attributed to the poorer rainfastness of the standard protective treatment as opposed to the metalaxyl-based treatments. This property has proved to be a major attraction to potato growers and contract applicators whose spraying operations are closely scheduled to maximise machine and manpower efficiency.

Hops

Trials with metalaxyl against hop downy mildew *(Pseudoperonospora humuli)* have been conducted in the U.K. since 1976 by Ciba-Geigy, ADAS and Wye College. Replicated small-plot trials showed that the fungicide gave an outstanding control of systemic infections and was safe to the crop. The results were not completely satisfactory due to the difficulties of conducting small plot trials in hops and the variability in crop growth and disease distribution in typical commercial crops. Thus, in 1978, an extensive series of single large-plot trials with comparisons of metalaxyl drench plus sprays and a standard fungicide spray programme was initiated.

In one trial, no foliar sprays of metalaxyl and only 3 sprays of the standard were applied. In the others the early season drench of metalaxyl replaced up to 3 sprays of a protectant fungicide during May. The result of these treatments in the 4 trials with the heaviest disease attack can be seen in Table 4, together with the total numbers of sprays applied per trial. The infections were almost entirely systemic as the dry weather from late June onwards prevented the build up of secondary leaf attack.

Table 4

Control of hop downy mildew and yield - grower trials 1978

Trial no.	Treatment	total % infection after soil drench: Systemic inf.[1] 5 wks	9 wks	Leaf inf.[2] 13wks	15wks	Cone yield Kgs/100 rootstocks	Total number of sprays
081	metalaxyl	0.4	0.4	0	0	431	3
	standard	20.1	35.1	15.0	0	431	13
083	metalaxyl	0	0	0	0	161	6
	standard	5.5	8.5	2.8	0	140	6
089	metalaxyl	0	0	0	0	182	0
	standard	4.3	31.9	14.8	4.2	171	3
091	metalaxyl	0	0	0	0	431	5
	standard	11.9	61.7	1.0	0	328	7

[1]as % rootstock infected [2]as % stems infected

Standard treatments were dithiocarbamate or copper-based HV sprays.
Trials 081 and 083 were in Herefordshire.
Trials 089 and 091 were in Kent.

The outstanding control of the systemic infections given by the rootstock treatment of metalaxyl can be clearly seen with high levels of diseased rootstocks being found in the plots treated with the growers standard. Considerable improvement in cone yield followed the superior disease control of metalaxyl in comparison with the standard and in addition, these plots did not require hand labour to remove diseased shoots ('Spike'), the cost of which frequently exceeds £50/ha.

The commercial experience with metalaxyl in hops in 1979 confirmed the above results, and the value growers see in the early season rootstock treatment. In a Ciba-Geigy survey to monitor the first experience with the product, growers representing 16% of the Kent hop area were visited. The survey showed that almost 50% of this sample area had been treated with metalaxyl; the bulk of applications being to the variety Wye Target, which is very susceptible to downy mildew and represents just over 30% of the Kent hop area. (Planted area statistics according to MAFF 1977). Disease control had been excellent, in contrast to comparison strips treated with protectant fungicides left purposely by the grower as a test or where supplies of the product were inadequate to treat the whole garden.

Even before the end of the first season of commercial use, it seems clear that metalaxyl has changed the standard disease control practices for the downy mildew susceptible varieties, particularly Wye Target. The secondary advantages of reduced labour requirements in crops treated by early season drench are expected to become increasingly evident as labour becomes more expensive and difficult to obtain.

Brassicas

A similar modification in disease control practice is expected to follow the commercial recommendations for metalaxyl use against downy mildew in brassica crops. *(Peronospora parasitica)*. This was reported at the last Brighton conference (Paulus et al. 1977) and has been confirmed in several trials since, including one conducted by the Plant Pathology Department, ADAS Evesham.

On an autumn sown cauliflower crop grown under frames at Luddington EHS, 9 sprays of the standard dichlofluanid were compared with metalaxyl as a single soil applied treatment, either incorporated pre-sowing or as a soil drench post-sowing and with 3 sprays of metalaxyl applied on a restricted protective schedule.

The results are given in Table 5:-

Table 5

Control of brassica downy mildew and of transplants yield - ADAS Evesham**1979

Treatment	Kg ai/ha	No. of applic-ations	No. of plantable plants/metre of row	Total No. of mildewed plants			
				Severe	Moderate	Slight	Uninfected
untreated	-	-	3.8	3.7	26.5	12.8	9.0
dichlofluanid sprays	0.84	9	9.0	0.3	5.3*	18.3	33.7*
metalaxyl soil-incorporated pre-planting	1.5	1	23.2*	0	0*	0*	41.2*
metalaxyl soil drench at planting	1.5	1	22.7*	0	0*	0.3*	49.5
metalaxyl sprays	0.8g/l HV	3	14.7*	0.5	0	1.0	53.7*

*significantly different from untreated at P = 0.05

**results of unpublished work by courtesy of ADAS Plant Pathology Department, Evesham.

Metalaxyl applied once to the soil, or 3 times as a post-emergent foliar spray gave virtually complete disease control whereas 9 sprays of the standard treatment gave only moderate disease control. As a consequence of the superior disease control by metalaxyl, a significant increase in the number of acceptable transplants was recorded from the plots treated with this fungicide.

Again, this result demonstrates the superior disease control given by fewer applications of metalaxyl. Labour costs are lower, a factor of particular importance to the frame-grown brassica crop where the removal of glass to allow spraying up to 9 times in a 6-8 week period considerably increases the labour requirement for spraying.

Other examples of completely new or substantial modifications of existing disease control techniques through the use of metalaxyl are being discussed at this conference. Apple storage rot *(Phytophthora syringae)* control by the use of pre-harvest soil drenches or post-harvest fruit dips is now a real possibility (Harris, in press). Major advances in the control of strawberry red core *(Phytophthora fragariae)* by soil drenches are also being presented (Montgomerie, in press) and good control has also been reported from ADAS trials following pre-planting root dip treatments (M. Simkin, personal communication).

Radical changes in disease control practice have already occurred through the use of metalaxyl for the control of lettuce downy mildew as a single peat block incorporated treatment or a restricted schedule of spray treatments and similar examples can be quoted from uses outside the U.K. e.g. incorporation in tobacco seed-beds for the combined control of blue mould *(Peronospora tabacina)* and blackshank *(Phytophthora nicotianae var. nicotianae)*; post-planting soil incorporated treatments for the curative control of root rot *(Phytophthora cinnamomi)* of avocado and the seed treatment of maize for protection against corn downy mildew *(Sclerospora spp.)*.

CONCLUSIONS

From the results presented it can be seen that metalaxyl has allowed a substantial revision of disease control practices for many crops. An increase in the interval between sprays of 50 to 100% is frequently possible by virtue of the greater persistence of metalaxyl within the crop and its systemic activity. Penetration into the plant is rapid and the subsequent transport to new growth, irrespective of weather conditions, allows a more reliable and complete disease control. This in turn permits optimal spray intervals to be adhered to, rather than being subject to shortening, following the removal of a protective fungicidal layer by heavy rain.

Long lasting soil applications giving disease control for at least 10 weeks have considerably simplified downy mildew control in crops such as hops, lettuce and brassicae and the ability to safely control a wide range of systemically acting downy mildews and root rots, represents a unique property which has lead to the rapid acceptance of metalaxyl in all the markets for which recommendations have been made.

Acknowledgements

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THE USE OF SURFACTANTS FOR THE CONTROL OF LETTUCE BIG-VEIN DISEASE

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Summary Lettuce big-vein disease, thought to be caused by a virus, is transmitted from diseased to healthy plants by zoospores of the root-infecting fungus Olpidium brassicae. A laboratory technique for assaying the toxicity of chemicals to zoospores showed that the zoospores were killed in dilute preparations of carbendazim (methyl-2-yl-benzimidazole carbamate) as BASF 3460F and in a formulation containing no carbendazim. As the latter formulation probably contained surfactants, different surfactants were tested and several found to be toxic to zoospores at concentrations of 1-10 ppm. These included Agral, Cetrimide, Deciquam 222, Ethylan CPX, Hyamine 1622, Manoxol/OT and sodium lauryl sulphate. When applied to the nutrient every four days Agral, at a concentration of 20 ppm, controlled the disease in a glasshouse lettuce crop grown by the nutrient film technique. BASF 3460F, at a concentration of 0.025 g per block, controlled the disease and prevented Olpidium root infection of lettuce grown in 4.3 cm^3 peat blocks containing Olpidium resting spores.

Résumé La "big-vein" de la laitue, qui est probablement causée par un virus, est transmise des plants infectés aux plants sains par l'Olpidium brassicae, un fungus qui infecte les racines. Une technique de laboratoire pour evaluer la toxicité des produits chimiques sur les zoospores a montré que les zoospores sont tués par des preparations diluées de carbendazime (carbamate de methyle benzimidazole yle-2) sous forme de BASF 3460F, et par une formulation ne contenant pas de carbendazime. Comme il est probable que cette dernière contenait des agents tensio-actifs, d'autres agents tensio-actifs ont été testés, et plusieurs se sont révélés toxiques pour les zoospores en concentrations de 1-10 ppm. Ils comprenaient l'Agral, le Cetrimide, le Deciquam 222, l'Ethylan CPX, l'Hyamine 1622, le Manoxol/OT, et le sulfate de sodium lauryl. Appliqué tous les quatres jours aux substances nutritives, l'Agral, en concentration de 20 ppm, a contrôlé la maladies dans des laitues cultivées en serre selon la technique du film nutritif. En concentration de 0,025 g par bloc, BASF a contrôlé la maladie, et empêché l'Olpidium d'infecter les racines de laitues cultivées dans des blocs de tourbe de 4,3 cm^3 contenant des spores dormants d'Olpidium.

INTRODUCTION

Big-vein is a lettuce disease in which the leaves of affected plants develop prominent chlorotic vein-banding and become ruffled and distorted. Plant growth is reduced and, if the symptoms are severe, the plants are unmarketable. One discovery that has evaded research workers for almost fifty years has been the cause of the disease. The causal agent is unknown and information concerning it is largely absent beyond the fact that it can be graft-transmitted (Campbell, Grogan and Purcifull, 1961; Tomlinson, Smith and Garrett, 1962). Previous workers have considered that the agent may be a virus, sometimes referred to as the lettuce big-vein virus (LBVV).

The phycomycete Olpidium brassicae (Wor.) Dang., is always present in the roots of naturally-infected diseased plants and big-vein can be transmitted experimentally by transferring Olpidium zoospores from diseased to healthy lettuce roots (Grogan, Zink, Hewitt and Kimble, 1958). Studies showed that zoospores carry LBVV if the fungus has developed in the roots of big-vein affected plants and that the fungus has a vector relationship with the virus (Tomlinson and Garrett, 1962; 1964).

Big-vein is soil-borne. This is because Olpidium releases virus-carrying zoospores from infected roots into the soil. The fungus also produces resting spores in the roots which contaminate the soil when the roots decay. Resting spores carry LBVV internally. They are thick-walled structures and remain viable in dry soil for many years before germinating in wet soil conditions. Their germination has not been observed but it is likely that when this occurs they release zoospores which infect lettuce roots.

As the disease depends on root infection by Olpidium, fungicides have been added to contaminated soil to control the disease but, so far, with little or no success. Such chemicals included zinc (Marlatt, 1959), quintozene (Marlatt and McKittrick, 1963), tetrachlor (Rich, 1960), pyroxychlor and metalaxyl (Kontaxis, 1978).

In 1977-78, new outbreaks of big-vein were reported in field and glasshouse crops in Norfolk, Surrey, Worcs, Beds and Herts. The disease occurred mainly in plants, which had been raised in peat blocks, after transplanting into the field. The most serious outbreaks, however, were in glasshouse lettuce crops grown in re-circulated nutrient solutions using the nutrient film technique (NFT).

In searching for new chemicals for the control of the fungus, studies showed that Olpidium zoospores were rapidly killed (<10 min) in low concentrations of certain surface-active agents (surfactants). Experiments are described in which these effects were first determined together with the results of preliminary trials on the control of the disease using a surfactant. The use of the fungicide BASF 3460F to prevent infection of lettuce seedlings grown in Olpidium-contaminated peat blocks is also described.

MATERIALS AND METHODS

Chemicals

The fungicides tested were carbendazim (methyl-2-yl-benzimidazole carbamate) as a 50% (w/w) wettable powder (Bavistin; BASF 3460F) and metalaxyl (methyl *N*-(2-methoxyacetyl)-*N*-(2,6-xylyl) alaninate) as a 50% (w/w) wettable powder (Ridomil 50 w.p.; Ciba-Geigy CGA 48988).

To observe the activity of zoospores in fungicide preparations, optically-clear solutions devoid of particulate material were made. This was done by placing 50 ml 0.1M potassium phosphate buffer, pH 7.0, in a 2.5 cm diam. dialysis bag (Visking, Scientific Instruments Centre Ltd, London) suspended for 3 days at 20°C in 500 ml of a stirred suspension (50 g/l) of carbendazim or metalaxyl in the same buffer. The contents of the bags were then removed, filtered and diluted in the same buffer before mixing with zoospore suspensions.

Zoospores

These were obtained by steeping Olpidium-infected lettuce roots in cold water or nutrient film mineral solution containing 0.05*M* glycine (Teakle and Gold, 1964) and 1% sucrose. After 15 min the solution was filtered through muslin to remove coarse debris, centrifuged for 10 min at 500-1000 *g* and approximately nine-tenths of the supernatant liquid removed with a Pasteur pipette and discarded. The sediment containing zoospores was resuspended by gentle agitation in one tenth of the original volume. Preparations contained large numbers of zoospores ($1-5 \times 10^6$ zoospores/ml) which remained motile for 20-30 h at 4°C.

Effect of chemicals on zoospores

Toxicity tests at 4°C were made by mixing one volume (0.5 ml) of a solution of the test chemical in mineral nutrient (MN) solution containing glycine and sucrose with three volumes (1.5 ml) of the zoospore suspension. Controls contained one volume of the same MN solution added to three volumes of the zoospore suspension.

The effects of chemicals on zoospores were estimated by comparing the motility of zoospores in test solutions with that of a control preparation. This was done by examining the zoospores in an unmounted drop of the test sample on a glass microscope slide at X100 magnification. In toxic solutions zoospores were killed rapidly (< 5 min) or they slowed down, developed 'jerky' movements and became motionless after some interval in the test solution. Zoospores were observed at 15 min intervals for 2-3 h and recorded on a 0-3 basis as either dead (0), with impaired movements (1-2) or motility indistinguishable from control zoospores preparations (3).

RESULTS

Laboratory experiments

Zoospores were unaffected by metalaxyl (500 ppm) but were killed in a dilute (1/100) solution of the dialysed suspension (50 g/l) of BASF 3460F. Further tests showed that zoospores were also killed in solutions of a similar concentration prepared from a formulation of BASF 3460F containing no carbendazim. As the blank formulation was considered likely to contain surfactants, tests were made to determine the effect of a variety of surfactants on *Olpidium* zoospores. The results obtained with a selection of ten surfactants representing various ionic types are given in Table 1.

The results showed that the relative toxicity of different surfactants to the zoospores varied but some proved to be toxic at very low concentrations. From the results it appeared that a surfactant might provide a means of controlling the disease in lettuce grown by the NFT system if the problems of translating laboratory results into field trials could be overcome.

Preliminary commercial trials with a surfactant

Trials with Agral (a non-ionic liquid surfactant containing 90% (v/v) alkyl phenol ethylene oxide condensate) were begun in January, 1979 at an NFT glasshouse site. The area of the experiment was 0.42 ha and was selected because of the high incidence of big-vein ($>$ 95%) in the two preceding lettuce crops. The concrete channels were not cleaned before starting the experiment in order to leave in the channels an appreciable amount of *Olpidium*-infected lettuce roots as inoculum. The experimental area was supplied with 42,000 litres of re-circulated nutrient solution. Whereas freshly made solutions of Agral were toxic to zoospores at a concentration of 5 ppm, it was known that similar solutions were not toxic if stored for 7 days at 20°C (Tomlinson and Faithfull, unpublished). Accordingly, Agral was slowly added to the supply tank to a concentration of 20 ppm and fresh Agral was subsequently added to the nutrient every four days.

After the addition of the surfactant, the area supplied with the treated nutrient was planted with 137,000 lettuce plants raised in peat blocks.

The treatment controlled the disease and at the end of 6-7 weeks, by which time the plants were marketable, none of the plants had developed symptoms. Microscope examinations of the lettuce roots failed to reveal the presence of *Olpidium*.

An adjacent area of lettuce, supplied with an untreated supply of nutrient served as control. At the end of the same period $>$ 90% of the plants had developed severe big-vein symptoms and their roots were infected with the fungus.

Using the same treatment, similar results were obtained in a further commercial trial. The application of a surfactant for the control of big-vein is likely to be successful when the whole of the nutrient solution feeding a concrete bed system can be thus treated.

Table 1

Effect of surfactants on *Olpidium* zoospores

Surfactant	Type[a]	Concn.[b] (ppm)	Zoospore activity[c] after various intervals (min) 5	60	120	270
Agral	N	1	3	3	3	3
		5	1	0	0	0
Ethylan CPX	N	5	2	0	0	0
		10	2	0	0	0
Spreadite	N	10	3	3	3	3
		50	3	0	0	0
Triton X100	N	10	3	3	2	1
		20	3	0	0	0
Tween 20	N	100	3	3	3	3
Manoxol O/T	A	10	2	0	0	0
		50	0	0	0	0
Marasperse CB	A	20	3	3	3	3
Sodium lauryl sulphate	A	1	3	2	1	0
		5	0	0	0	0
Cetrimide	C	1	3	2	1	0
		5	0	0	0	0
Deciquam 222	C	1	3	1	0	0
		5	1	0	0	0
Hyamine 1622	C	1	3	3	3	3
		5	1	0	0	0
Control		-	3	3	3	3

[a] Non-ionic (N), anionic (A) or cationic (C)
[b] Diluted in MN solution containing 0.05M glycine and 1% sucrose
[c] Effects assessed on 0-3 scale. Zoospores dead (0), with impaired movements (1-2) or normal (3).

Control of *Olpidium* by BASF 3460F in peat-block raised lettuce

Studies on the use of surfactants in NFT systems is only a part of a larger problem on the dissemination and control of big-vein. An additional problem is the occurrence of the disease in glasshouse complexes used for the production of large numbers of peat-block raised young lettuce prior to their despatch and planting as field crops. Evidence has accumulated and tests have confirmed that some outbreaks in field crops originated from infection of young plants which, at their time of despatch, did not show the symptoms of the disease.

To control the disease in these situations, experiments were started to test the effectiveness of certain fungicides mixed with peat prior to the peat being moulded into blocks and sown with lettuce seed. Immediately after sowing, each block received 2 ml of a water suspension of pulverised lettuce roots, containing 100-200 *Olpidium* resting spores.

The results of two experiments on the control of lettuce seedling infection by block-incorporation of BASF 3460F is shown in Table 2.

Table 2

Control of lettuce big-vein in contaminated peat blocks by BASF 3460F

Amount BASF 3460F (g) per peat block[a]	Percentage big-vein[b] Experiment 1 32 days	Experiment 1 46 days	Experiment 2 30 days	Experiment 2 49 days
0	75	90	40	80
0.005	-	-	15	50
0.010	0	0	5	25
0.025	0	0	0	0
0.050	Phytotoxic	-	-	-

[a]4.3 cm^3 peat blocks. Fungicide was mixed with peat before the peat was wetted for preparation into blocks.

[b]Expts 1 and 2 contained respectively 10 and 20 plants per treatment. At commencement, each seeded block was contaminated with 2 ml containing about 200 Olpidium resting spores.

The results showed that plants grown in contaminated peat blocks containing 0.025 g BASF 3460F per block did not develop the disease and a microscopical examination of their roots failed to detect Olpidium. Further trials with BASF 3460F as a block-incorporated fungicide for big-vein control are now in progress.

DISCUSSION AND CONCLUSIONS

The object of this research was to find a method of controlling the big-vein disease of lettuce. Studies were advanced by developing a standard laboratory method of screening fungicides and other chemicals for activity against zoospores of Olpidium brassicae (Tomlinson and Faithfull, 1979).

By microscopic examination of zoospores in solutions of BASF 3460F and of a blank formulation of BASF 3460F containing no carbendazim, it was concluded that the toxicity of the solutions was probably due to their surfactant content.

Tests with known surfactants at low concentrations showed that several of them were toxic to zoospores. When the surfactant Agral was tested under commercial conditions, it was effective in controlling big-vein in a glasshouse crop when added at a concentration of 20 ppm to the nutrient in which the lettuce plants were grown.

Other investigations showed that BASF 3460F prevented big-vein in lettuce grown in 4.3 cm^3 peat blocks contaminated with Olpidium. When applied at the rate of 0.025 g per block, the plants failed to develop disease symptoms and their roots were free of Olpidium.

This account deals briefly with the progress of a research programme on the development of practical methods for big-vein control. The problem is by no means completely solved, however, and more trials extending over several seasons may be necessary before it will be known whether the disease can finally be controlled in the situations described.

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