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EXPERIMENTS FOR THE CONTROL OF DOWNY MILDEW (PERONOSPORA VICIAE) IN VINING PEAS AND BROAD BEANS

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Summary Experiments carried out on peas (*Pisum sativum*) for the control of downy mildew (*Peronospora viciae*) indicated that single applications of fungicides aluminium tris(ethyl phosphonate), furalaxyl and metalaxyl, made at the seedling stage, were ineffective when the crops were severely infected. Three applications of aluminium tris(ethyl phosphonate) plus mancozeb, metalaxyl, metalaxyl plus mancozeb, milfuram, milfuram plus maneb, were more effective under less disease pressure, but did not give acceptable control or result in increased yields. The control and beneficial effects on the crop with these materials in broad beans (*Vicia faba L*) were better. Seed treatments of aluminium tris(ethyl phosphonate), furalaxyl and metalaxyl gave partial control of primary systemic infections in seedlings and this appeared to reduce later secondary infection. Applications of mancozeb were generally less effective, particularly against systemic infection of the growing point. The herbicide dinoseb-amine was also ineffective in preventing the systemic infection.

Sommaire Les expériences faites sur les pois (*Pisum sativum*) pour enrayer la maladie "downy mildew" (*Peronospora Viciae*) indiquent que les seules applications des fongicides aluminium tris(ethyl phosphonate), furalaxyl et metalaxyl, faites à l'étage du jeune plant se sont montrées inefficaces dans le cas où la récolte était sévèrement infectée. Si la sévérité de la maladie n'était pas si grave, trois applications d'aluminium tris(ethyl phosphonate) avec mancozeb, metalaxyl, metalaxyl avec mancozeb, milfuram, milfuram avec maneb, se sont montrées plus efficaces, mais ceux-ci n'ont pas donné ni d'enrayement acceptable, ni de récolte augmentée. Dans le cas de grosses fèves (*Vicia faba L*) l'enrayement et les effets avantageux sur la récolte après l'application de ces produits chimiques étaient meilleurs. Le traîtement des graines avec aluminium tris(ethyl phosphonate), furaxyl et metalaxyl donnait l'enrayement partiel des infections primaires et systémiques dans les jeuns plants et il paraît que ce traîtement réduit l'infection secondaire plus tard. Les applications de mancozeb étaient généralement moins efficaces, particulièrement contre l'infection systémique de la pointe de croissance. L'herbicide dinoseb-amine était aussi inefficace dans la prevention de l'infection systémique.

INTRODUCTION

Downy mildew (*Peronospora viciae* (Berk.)Casp.) is the most common foliar disease of the U.K. pea crop, affecting the plants at most stages of their development. Although less frequent, infection of broad beans can also occur. The incidence of the disease is higher in wet seasons and is particularly associated with the early spring sowings.

Later plantings made under drier conditions are generally less severely affected. Olafsson (1966) reported that the fungus required the presence of rain or dew on the plant leaves for at least 3 hours during inoculation with sporangia and that these were only produced if the relative humidity exceeded 90% for at least 12 hours. High temperatures and dry weather retarded the attack.

Early signs of attack are the systemic infection in emerged seedlings caused by oospores in the soil. Such seedlings are stunted, paler in colour and the undersides of the leaves are covered in a downy greyish-violet growth. These infections serve as foci for secondary, spread by wind-blown sporangia. The secondary infection takes the form of localised patches, mostly on leaves, but occasionally on stems and other parts of the plant including the pods. This secondary infection may affect the growing point, in which case the whole of the top of the plant may become systemically infected.

The infection can affect the yield in various ways. The systemically infected seedlings very often die but even if they do produce sound tillers they seldom contribute to the green pea yields due to later maturity. If a high percentage of seedlings are infected the effective plant population is reduced below the optimum (King, 1967); occasionally crops are so severely affected that they are ploughed-up. Pegg & Mence (1972) suggest that the local lesions on the leaves would be insufficient to reduce significantly the pool of photosynthates and thus the yield, since the plants would probably compensate for the loss of the affected leaf area. They did find, however, that the secondary systemic infection which affected the top of the plant had a major effect on yield by reducing the number of flowering nodes, flowers and pods produced at each node. In spite of this yield losses in their work did not exceed 4% of the green seed crop over two seasons, whereas Campbell (1935) recorded losses between 5 and 40% and Olafson (1966) up to 30%. A further problem caused by the disease is discolouration of seeds, which may result in the rejection of a vining crop by the processor.

In spite of the testing of cultivars for resistance to the disease (King & Gane 1965; Gent 1966; Ryan 1966), it has not yet been possible to produce acceptable cultivars with a high degree of resistance and many of those grown commercially can under some conditions be severely infected. Attempts in the U.K. at control using chemicals has in the past been disappointing (King & Gane 1965; Ryan 1966), although there have been reports (Allard 1971; Olafsson 1965), of useful control using dithiocarbamate fungicides. With the availability of new materials active against this group of fungi and claimed to have systemic activity, it was decided to carry out field experiments testing both seed and foliar treatments. The results of two years experiments are presented in this paper.

METHODS AND MATERIALS

All experiments were of randomised block design with three or four replications and a minimum plot size of 0.001 ha. One experiment in 1978 was laid down on the Thornhaugh trial ground. All other experiments were carried out in commercial crops.

The seed treatments were applied as slurries, the wettable powder formulations being mixed with water to form a paste and the seed was then coated using an 'end over end' seed dresser, good cover being achieved. Foliar applications were made with a van der Weij plot sprayer fitted with cone nozzles in 560 l/ha of water, control plots were sprayed with water. In 1978 no wetter was added, but in 1979 Agral at a concentration of 0.001% was added to all spray applications. The materials were all wettable powder formulations, except dinoseb-amine, and doses are presented in kg/ha of active ingredient. Where seed treatments had been used the

the plants were assessed on 2.7 m of row per plot when they had five to six expanded leaves. At this stage total plant emergence and primary systemically infected seedlings were counted together with those exhibiting secondary infection. All other assessments were made on 20 plants and they were grouped according to the percentage of leaf area affected by lesions and the percentage of affected pods was also recorded.

The pea experiments were cut by hand when they had reached freezing maturity and were then threshed using a plot viner. After cleaning the produce was weighed and the maturity measured using a tenderometer. Samples were taken and processed for taint testing.

The crop and application details are shown in Table 1.

Table 1

Site details

Location	Cultivar	Sown	Application date(s)	Growth stage No. leaves	Infection level † Primary	Secondary
1978						
1 Thornhaugh	K. Wonder	17/3	9/6	10-11	40	Low
2 Upwell	Scout	10/3	16/5	5	73	Heavy
3 Spridlington	Avola	12/3	18/5	5	81	Heavy
1979						
4 Wiggenhall	Sprite	11/4	27/5,4/6,14/6	5,8 & 10	16	Moderate
5 Burwell	Beryl	-	28/6 & 11/7	10 & 12	-	Heavy

Key: † Infection level at the first application date.
Primary-percentage of primary systemically infected plants.
Secondary-Degree of secondary infection.

RESULTS

Peas - 1978

The results of assessments made for the control of primary systemically infected seedlings by seed treatments and of secondary infection by seed or foliar treatments are shown in Table 2. All three seed treatments appeared to reduce the primary infected seedlings by approximately 50% and also reduced the secondary infection by a similar level at the 6th July assessment date. They did not reduce total emergence or affect seedling development. The infection did not develop further until towards flowering and the foliar applications were made on 9th June. In assessments made on 6th July there were indications of some reduction in the severity of infection as measured by the average percentage leaf area affected and the percentage number of infected pods. The seed treatments did have some effect on the late infection and disease levels were similar for seed and foliar applications. Metalaxyl and aluminium tris(ethyl phosphonate) were slightly better than furalaxyl. The experiment was not harvested for yields following bird damage.

The results of assessments made on two experiments carried out in commercial crops appear in Table 3. In these experiments only a single spray application was tested, made when the plants had five expanded leaves. The assessments showed that the treatments had not reduced the secondary infection and the disease became progressively worse at both sites, to the extent that the crop at site 3 was too poor to warrant commercial harvesting. Neither site was harvested for experimental yields.

Table 2

Results of assessments for disease control at site 1 - 1978

Material	Application Seed	Application Spray	Rate ≠ kg a.i. /ha	% plants infected A	% plants infected B	% leaf infection 6th July 0-10	10-40	>40	% pod infection 6th September
furalaxyl	✓	-	-	27	6	70	24	6	8
"	✓	✓	0.2	-	-	69	26	5	10
"	-	✓	0.2	-	-	75	18	7	8
"	-	✓	0.4	-	-	72	21	7	7
metalaxyl	✓	-	-	20	2	82	13	5	5
"	✓	✓	0.2	-	-	93	7	0	0
"	-	✓	0.2	-	-	81	15	4	7
"	-	✓	0.4	-	-	92	8	0	0
aluminium tris	✓	-	-	21	7	86	9	5	3
(ethyl phosphonate)	✓	✓	1.5	-	-	82	16	2	3
"	-	✓	1.5	-	-	66	27	7	5
"	-	✓	3.0	-	-	72	22	6	2
control (water)	-	-	-	40	13	58	35	7	13

Key: ≠ Seed treatment rate 2 g/kg seed of product (furalaxyl 50% w.p. & aluminium tris(ethyl phosphonate) 80% w.p.).
A Primary systemically infected seedlings.
B Seedlings with secondary infection.

Table 3

Results of assessments for disease control at sites 2 & 3 - 1978

Material	Rate kg a.i./ha	% plants affected by secondary infection 2nd June Site 2	Site 3
furalaxyl	0.2	22	31
"	0.4	19	22
metalaxyl	0.2	20	27
"	0.4	25	28
aluminium tris(ethyl phosphonate)	1.5	33	38
" "	3.0	47	30
control (water)	-	26	29

Peas - 1979

In view of the lack of control given by a single application in the experiments carried out in 1978 a series of applications was tested in 1979 and the results appear in Table 4, the assessments being made on 19th June.

It can be seen that three applications reduced the number of plants with secondary infection including those affecting the growing point and top of the plant. The percentage of plants with infection on the pods was relatively low but again certain treatments appeared to have reduced the degree of infection. The most effective treatments were metalaxyl, milfuram + maneb, aluminium tris(ethyl phosphonate) + mancozeb and mancozeb. The herbicide dinoseb-amine, only applied at the first application date, gave a useful effect on later leaf infection by scorching the primary infected seedlings and the infected lower leaves of secondary infected plants, but there was no indication that it had reduced pod infection. In spite of the reduction in disease none of the treatments gave significant yield increases compared to the untreated control plots.

Table 4

Assessments & yield data from site 4 - 1979

Material	kg a.i./ha	% plants infected A	B	C	Yield (tonnes/ha)	T.R.
metalaxyl	0.25	6.6	0	0	5.35	98.8
metalaxyl + mancozeb	0.15 + 0.72	13.4	0	2.8	4.89	101.0
milfuram	0.25	16.6	5	2.8	4.93	98.5
milfuram + maneb	0.25 + 1.4	5.0	3.3	0.8	5.08	98.9
aluminium tris(ethyl phosphonate)+mancozeb	1.32 + 0.78	5.0	3.3	0	5.38	96.8
mancozeb	1.4	3.3	1.7	3.0	5.16	97.0
dinoseb-amine ϕ	1.9	15.0	6.7	6.8	4.86	101.8
control (water)	-	38.3	18.3	4.0	5.09	99.5
Sig. at P = 0.05%					N.S.	N.S.
S.E. as % of gen. mean					7.5	4.2

Key: A Localised leaf infection (5 - 20% leaf area)
B Systemic infection of growing point. C. Pod infection.
ϕ Only applied on 27th May. T.R. Maturity as measured by the tenderometer.

Table 5

Assessments and yields (broad beans) at site 5 - 1979

Material	Rate kg a.i./ha	11th July A	17th July B	C	D	Yield pods t/ha
metalaxyl	0.25	5.8	43	3	0	17.08
metalaxyl + mancozeb	0.15 + 0.72	4.6	57	7	0	18.12
milfuram	0.25	9.2	50	3	0	16.37
milfuram + maneb	0.25 + 1.4	7.3	53	10	0	18.08
aluminium tris(ethyl phosphonate)+mancozeb	1.32 + 0.78	5.7	37	6	0	18.96*
mancozeb	1.4	18.9	36	40	17	16.12
control (water)	-	22.1	17	53	30	15.04
S.E. as % of gen. mean	-	-	-	-	-	11.70

Key: A Average % leaf area infected on uppermost 4 leaves.
B % plants with less than 10% of the upper leaf area infected.
C % plants with 10-50% of the upper leaf area infected.
D % plants with more than 50% of the upper leaf area infected.
* Significant difference from the untreated @ P = 0.05.

Broad beans - 1979

The crop was treated at an advanced growth stage when almost every plant had infection on all the leaves including the new growth at the top of the plant. The results of assessments carried out after the first and second applications appear in Table 5 together with the yield data. All the treatments reduced the infection on the new growth, although mancozeb was less effective than the other materials which eliminated the heavy infection completely. Observations carried out on 3rd August ten days prior to harvest, showed that the disease was no longer affecting the new growth and that the most effective treatments had slightly reduced the loss of leaves from the nodes present when sprayed. Although the yields from all the treatments were higher than the untreated control plots, only that for aluminium tris(ethyl phosphonate) plus mancozeb reached statistical significance. There was a suggestion that the three mixtures with dithiocarbamate fungicides were giving the highest yields.

DISCUSSION

The results of these experiments carried out in peas have generally been disappointing. Single sprays applied at an early growth stage had no affect on heavy attacks in two commercial crops in 1978, while a later application at site 1 reduced the leaf and pod infection at harvest by only 20-30%. Seed treatment at this site gave partial control of primary infected seedlings and some reduction in early and late secondary infections. They appeared to be as effective as later foliar sprays, but again the control achieved was below the level which would be required commercially. It is unlikely that the seed treatments were persisting in the plant until harvest. The effect on secondary infection was probably due to the reduction in the number of the primary infected seedlings and thus the number of air-borne sporangia. Unfortunately no disease developed on a similar experiment laid down in 1979, and thus the seed treatment results could not be verified.

The poor control in 1978 from foliar treatments was thought to be due to either poor uptake by the plant or an insufficient number of applications. In 1979 additional wetter was added to all the treatments while two or three sprays were applied. A slightly better level of control was achieved in the pea experiment, but this was obtained under less disease pressure than the previous year. None of the treatments increased yield compared to the untreated control and as suggested by Pegg & Mence (1972) pea plants may be able to compensate for localised leaf lesions. However, 18% of the plants on the untreated control were affected by systemic infection of the growing point which reduced their pod-bearing potential and which these workers claimed had a major effect on yield. It is therefore surprising that although the treatments gave good control of this infection, no yield increases occurred.

The treatments appeared to be more effective in the single broad bean experiment carried out in 1979. Infection was very severe and two sprays gave good levels of control, which appeared to be reflected in higher yields.

Using the data from site 1 in 1978 it was possible to detect slightly better activity with metalaxyl than with furalaxyl and aluminium tris(ethyl phosphonate). Similarly in 1979 metalaxyl, milfuram plus maneb and aluminium tris(ethyl phosphonate) plus mancozeb appeared to perform marginally better than the other materials. In the 1979 pea experiment metalaxyl alone seemed better than a reduced dose of metalaxyl plus mancozeb, while the addition of maneb to milfuram slightly improved its effect. Mancozeb alone gave some control of early secondary infection in peas, but did not appear to be effective against disease affecting the growing point and this was particularly noticeable in the broad bean experiment. The contact herbicide dinoseb-amine appeared to give some reduction in early secondary infection, presumably due to the removal of infected leaf tissue which does not possess sound leaf wax, and this is in agreement with Gent (1966) and Olafsson (1966). Later systemic infection of the growing point was not controlled in this work.

The experiments have shown that the new range of fungicides possessing systemic activity have greater activity against Peronospora viciae than protectant materials such as mancozeb, but it has not yet been possible to demonstrate in small plot experiments that commercially acceptable levels of control can be achieved. In small plot experiments, laid out in commercial crops, the fungicides are under more disease pressure through air-borne sporangia coming from the untreated crop than if the whole crop was treated. This may be an explanation for the poor results obtained against the disease in peas, which conflict with results obtained in other crops against similar diseases. One of the main problems associated with Peronospora viciae in peas and broad beans is that the infection occurs very early in the crop's development. The systemically infected seedlings which emerge act as a source of infection for secondary spread, and these seedlings can often be found in crops for a considerable time, certainly up to the time the crop is flowering. Effective seed treatments to remove this early source of infection, linked with later foliar applications may eventually prove to be necessary for satisfactory control of this disease.

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