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A preliminary investigation of the epidemiology, crop loss & control of powdery mildew on processing tomato

VG138

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ABSTRACT

The tomato powdery mildew in Australia is a new species of powdery mildew never reported before on tomatoes. It develops characteristic spider-like (arachnoid) lesions on the surface of the leaves. Infection occurs on the stem, petioles, calyxes and leaves, and develops from the lower leaves up the canopy. Because of the severity of symptoms it is thought that tomatoes are not the natural host of this fungus. It is very similiar to the mildews found on Silver-leaf nightshade, Kangaroo apple, Tamarillo, Eggplant, Ornamental tobacco and Petunia. Replicated fungicide trials were conducted on several commercial sites at Timmering and Undera. Sulphur proved to be superior to the systemic fungicides; Bayfidan, Calixin, Saprol and Tilt, during the 1991/92 tomato season, when applied at an early stage of disease development.

INTRODUCTION

Powdery mildew has been a widespread problem on tomato crops in Northern Victoria and Southern NSW since the 1987/88 season. It mostly affects early and mid-season crops, appearing during the February-March period when plants have set fruit. The disease causes leaf dessication, creating risks of severe sunscalding and heavy yield loss where younger crops are infected. Yield losses of up to 44% from sunburn damage have been reported as a result of this disease.

The identity and source of the tomato powdery mildew is not known. It is not the typical powdery mildew, *Leveillula taurica*, which is widespread in the tomato growing areas of California. Except for an isolated occurrence in 1886, in the Upper Yarra Valley of Victoria, powdery mildew has not been seen in Australia on tomatoes until 1980/81 when it was reported on glasshouse tomatoes in Bendigo, Victoria and in Murray Bridge, South Australia. It is therefore a relatively new disease to this country. Since tomatoes are not grown on the affected sites between May and September the source of this disease is also not known. It must overwinter either on tomato crop residue or on an alternative host.

The only fungicide registered for the control of powdery mildew on tomatoes in Victoria is Lime-Sulphur. But it is not currently being used because of incompatibility as a tank mix with other sprays. Sulphur, which is registered for control of mites is commonly used as a protectant spray against mites and powdery mildew.

However, many growers have found that sulphur does not always work, and that their crops still become severely damaged. It is not certain that sulphur can effectively control powdery mildew during heavy infestation, and it is therefore recommended as a preventative rather than curative spray.

A preliminary investigation was carried out to determine the identity, source and basic epidemiology of the pathogen infecting processing tomato crops. Control potential of a small range of contact and systemic fungicides was also assessed.

METHODS

1. IDENTIFICATION AND SOURCE OF THE PATHOGEN

Commercial tomato crops were assessed for fungal propagules in crop residue and for alternative hosts of the disease throughout the growing season. The morphology of the pathogen was described and compared with powdery mildew from potential alternative hosts. Cross-innoculations were then carried out in the glasshouse between tomato and potential alternative hosts.

2. EPIDEMIOLOGY OF THE PATHOGEN

i) Symptoms of powdery mildew
Development of powdery mildew was studied in the field and in the greenhouse in order to identify characteristic symptoms of the disease, that could facilitate its early detection in the field. In the glasshouse individual healthy tomato leaflets were tagged and inoculated by brushing infected leaflets (from the field) against healthy leaflets.

ii) Measurement of environmental conditions
In order to establish any correlations between meteorological conditions and key infection periods, ambient temperature and relative humidity were continuously monitored at the fungicide trial sites from late December for two months. Temperature and relative humidity sensors connected to a datalogger were placed in a weather shelter built to specifications of the Bureau of Meteorology.

3. CONTROL OF POWDERY MILDEW IN THE FIELD

Fungicide trial sites were established on commerial tomato crops at Timmering (site 1) and Undera (site 2) at the start of the growing season to determine crop loss and control potential of a small range of fungicides. Sulphur and Lime-sulphur were compared against two systemic fungicides, Bayfidan and Tilt, for efficacy against tomato powdery mildew.

Plots were sprayed either:

a) throughout the growing season at 14 day intervals (to prevent infection and to obtain a measure of economic yield loss due to powdery mildew).

b) when diseased plants were first observed in the crop (to prevent further infection and spread).

c) when disease well established (to control existing infection).

Disease incidence was assessed weekly at the start of the growing season up to first detection of powdery mildew. 120 mature leaflets were sampled from randomly selected plants and assessed microscopically for powdery mildew sporulation.

Two further trial sites (3 & 4) were establised at Timmering on tomato crops with low levels of powdery mildew infection. Control potential of six fungicides was assessed against an unsprayed control treatment.

The following chemicals were tested for efficacy against tomato powdery mildew:

Sulphur	RT Micronised Sulphur Fungicide at 3.5 kg/ha
Lime-sulphur	Rhone-Poulenc Lime-Sulphur at 1L/100L
Triadimenol	Bayer Bayfidan 250EC fungicide at 560ml/ha
Propiconazole	Ciba Geigy Tilt 250EC fungicide at 560ml/ha
Triforine	Shell Saprol fungicide at 1.5L/ha
Tridemorph	Hoechst Calixin fungicide at 500ml/ha (site 3) and 300ml/ha (site 4)

Bayfidan, Calixin, Saprol and Tilt will henceforth be referred to as the systemic fungicide treatments.

Fungicides were applied once at site 3 and twice at site 4 at ten day intervals when tomato crops were nearing maturity. Russet mite (*Aculops lycopersici*) caused considerable damage at site 3 and made it difficult to distinguish foliar damage due to powdery mildew. Consequently the miticide Dicofol (V-9 Kelthane MF) was applied at 100ml/ha over site 4 to prevent mite infestation.

All experiments were set out in a randomised block design with each treatment replicated four times. Plots within treatments consisted of 3 rows 10m long. Only the center row of each plot was assessed for disease severity and the two outer rows acted as guard rows. Fungicides were applied with a 1.5m hand held boom sprayer with 4 flat fan nozzles, held 400mm above the plant canopy, at 200 kpa in a volume of 331L/ha.

The plots were visually assessed biweekly for foliar damage due to powdery mildew until harvest. Fifty mature leaflets/plot were randomly sampled at harvest (only at site 4) to measure percentage of leaflets and percentage leaf area with powdery mildew infection and sporulation.

Crop yield and quality (soluble solids) were measured at crop maturity by harvesting a 2m section of tomato plants from the central row of each plot.

RESULTS

1. IDENTIFICATION AND SOURCE OF THE PATHOGEN

The tomato powdery mildew in Australia is not *Erysiphe chichoracearum* as originally believed but an as yet unidentified species never described before on tomatoes. It is an *Oidium* species, similiar to *Oidium longipes* described on eggplant in the Netherlands, and is characterised by having long conidiophores, with elongated foot cell(s) and raised basal septum (figure 1). Conidia are formed in chains, are barrel-shaped and do not contain fibrosin bodies. Appressoria are nipple-shaped and are either single or in clusters. Germinated germtubes are unbranched.

Because of the severity of symptoms on tomatoes and because no fungal propagules were found on tomato crop residue, it is most likely that tomatoes are not the natural host of this mildew and that it comes from another solanaceous host. The alternative host must be a winter growing annual or perennial allowing the mildew to survive between May and September, when tomatoes are not grown.

Several solanaceous plants have been identified with powdery mildews apparently the same as the tomato mildew. They are Silver-leaf nightshade (*Solanum elaeagnifolium*), Kangaroo apple (*Solanum aviculare*), Tamarillo or Tree tomato (*Cyphomandra betacea*), Eggplant (*Solanum melongena*), Ornamental tobacco (*Nicotiana alata*) and Petunia (*Petunia* sp.). Cross-inoculation tests between these plants and tomatoes will be carried out to determine if they are the same pathogen. The mildew has not been found on Black nightshade or Potato.

2. EPIDEMIOLOGY OF THE PATHOGEN

i) Symptoms of powdery mildew

Since detection of the fungus in the field is difficult, part of the research last season focused on identifying symptoms characteristic of powdery mildew. The following observations were made:

1a. Powdery mildew initially develops characteristic spider-like lesions (Plate 2b) on green tissue which eventually turns yellow. As more and more lesions form the leaf takes on a dirty yellow appearance (Plate 2a).

1b. These lesions develop necrotic centers which expand and large areas of the leaf can turn black. The fungus may continue to sporulate and the lesions can become covered by a white mass of spores. The leaf eventually withers, dries out and turns a light brown. The black spider-like infected areas are usually still obvious on the surface of the dead leaves.

1c. The fungus is most visible as a white powder on the leaf surface. However the spores (conidia) and spore-bearing structures (conidiophores) which give the leaf its powdery appearance can only survive on healthy tissue and rapidly disappear in the field as the leaf becomes necrotic. Infections in glasshouse grown tomatoes usually do not cause necrosis and produce abundant white powdery spore masses.

2. The symptoms are very similar to those of tomato russet mite which commonly infest plants at the same time or just after powdery mildew infection. Leaves infected with russet mite, however, take on a glossy, bronzy appearance. Cream-colored, torpedo-shaped mites can be observed with a strong hand lens or microscope on the undersurface of the leaf.

3a. The lower part of the plant, where the leaves are older, is the first to be infected. Older leaves tend to develop more severe symptoms than younger leaves.

3b. Infection occurs on the stem, petioles, calyxes and leaves. Infections on petioles can result in death of the entire leaf, and infections on the mid-vein of a leaflet can result in death of distal portions of the leaflet.

3c. Mildew can occur on both sides of the leaf but is usually more abundant on the upper surface and along the veins. The fungus appears to thrive more within the canopy.

3d. Infected and dead leaves persist on the plant.

4a. Field observations indicate that powdery mildew is more severe on crops under stress from other pests and diseases (ie, russet mite) and environmental factors (ie, dry soils).

4b. Since the disease is spread by air-borne spores initial infection is usually from the windward side of the crop.

5. Powdery mildew tends to be more prevalent in late summer than spring and subsequently affects mid-season crops. The fungus was first observed in the Rochester area on December 23, however mildew infection was not conspicuous on crops until late January.

ii) Measurement of environmental conditions

In Northern Victoria the disease is generally favoured by dry, warm weather and relatively dry soil conditions which occur when irrigation is turned off towards harvest. Rain can damage mildew conidiophores and conidia so there's generally a lower incidence of mildews in higher rainfall areas.

There is an interaction between temperature, humidity and light, however observations over several years are required to establish reliable correlations between meteorological data and key infection periods.

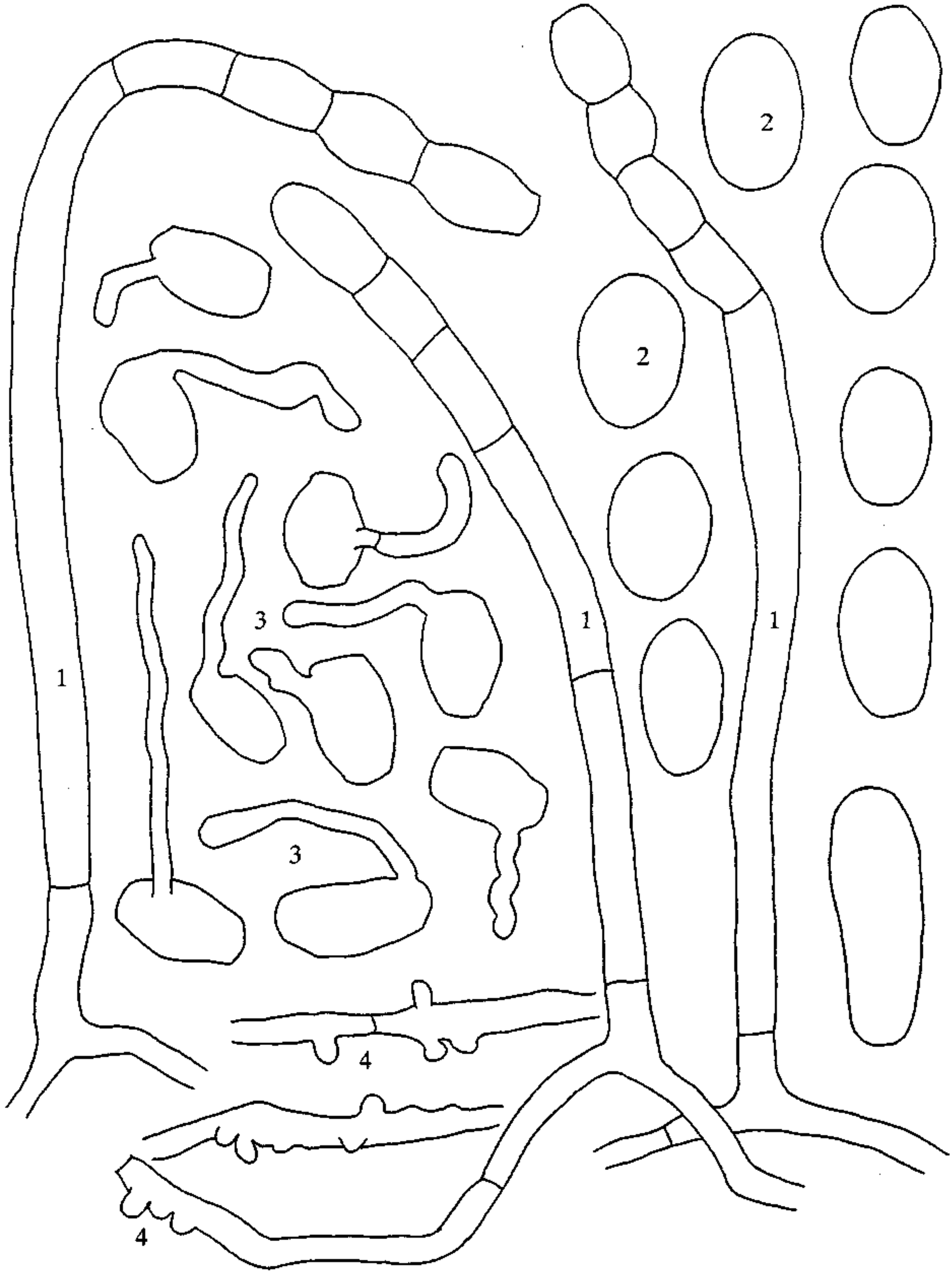

Figure 1. Tomato powdery mildew fungus; conidiophores and conidia (1,2), germinated conidia (3), and appressoria (4).

3. CONTROL OF POWDERY MILDEW

i) Sites 1 & 2

An economic measure of yield loss due to powdery mildew could not be obtained since both experimental plots did not become infected with the disease.

At Timmering (site 1) powdery mildew was first detected microscopically on leaflet samples on December 23 adjacent to the experimental plots. The tomato crop was aerial sprayed twice in January with sulphur. On January 20, three weeks prior to harvest, powdery mildew infection was observed in a tree-lined corner of the paddock, but the disease did not spread to the experimental site. This corner area was presumably missed by the aerial spray of sulphur. Consequently sulphur was effective in preventing build up of mildew in the crop when applied at a very early stage of disease development.

At Undera (site 2) the tomato crop and experimental site were also aerial sprayed with several applications of sulphur. Leaflet samples taken weekly up to harvest did not detect any powdery mildew in the crop.

TABLE 1. Visual Assessment of Leaf Damage[x] at Timmering - Site 3

Treatment	Leaf Damage	
	1st Spray	Harvest
Lime-sulphur	1.2[z]	2.5 a[y]
Sulphur	1.0	2.8 ab
Saprol	0.5	3.8 ab
Bayfidan	0.8	4.0 abc
Tilt	1.2	5.8 c
Calixin	1.0	6.0 c
Control	1.0	4.8 bc

[x] On 0-8 disease scale: 0=no damage; 1=0-1%; 2=2-5%; 3=6-10%; 4=11-25%; 5=26-50%; 6=51-75%; 7=76-99%; 8=100%

[y] Means followed by a different letter are significantly ($P=0.05$) different according to Fisher's Least Significant Difference (LSD)

[z] Discreteness of the data preclude ANOVA

ii) Sites 3 & 4

Powdery mildew was first observed at sites 3 and 4, three weeks prior to harvest on January 21 and February 10 respectively.

At site 3 the crop became infested with tomato russet mite and damage due to powdery mildew was impossible to distinguish from mite damage at harvest. Powdery mildew and mites did not spread onto the experimental plots until the week prior to harvest. Visual assessment (Table 1) of the trial plots showed that the contact fungicides, particularly Lime-sulphur, performed better than the systemics. But this could have been due to their more effective control of mites. Leaf damage on the Tilt and Calixin treatments included burn damage, presumably from excessive rates of fungicide. Consequently the rate of Calixin was reduced from 500ml to 300ml/ha at site 4.

No significant differences in red and green fruit yield, fruit weight, and soluble solids (Table 2) between the fungicide treatments and control were obtained.

TABLE 2. Effect of fungicides for control of powdery mildew on yield and quality of harvested tomatoes at Timmering-Site 3

Treatment	Yield (t/ha)		Fruit Weight (g)	Soluble Solids (%)
	Ripe	Green & Rotten		
Lime-sulphur	49	6	44	5.0
Sulphur	49	6	43	5.2
Saprol	38	6	43	5.1
Bayfidan	46	5	40	5.2
Tilt	39	5	44	5.0
Calixin	52	6	43	4.7
Control	41	6	43	4.9
LSD (P=0.05)	12	ns	3	0.4

ns = not significantly different

At site 4 Dicofol was effective in preventing mite infestation. Disease pressure was high around the experimental site since the remainder of the crop was not sprayed with sulphur, enabling build-up of powdery mildew inoculum to occur.

Sulphur proved to be superior to the systemic fungicides; Bayfidan, Calixin, Saprol and Tilt, during the 1991/92 tomato season, when applied at an early stage of disease development.

TABLE 3. Visual Assessment rating of Leaf Damage[x] due to powdery mildew at Timmering - Site 4

Treatment	Leaf Damage	
	1st Spray	Harvest
Sulphur	1.0[z]	1.5 a[y]
Lime-sulphur	1.2	2.2 a
Saprol	1.2	3.0 ab
Tilt	1.7	3.0 ab
Bayfidan	1.2	2.2 a
Calixin	1.2	3.0 ab
Control	1.7	4.5 b

[x] On 0-8 disease scale: 0=no damage; 1=0-1%; 2=2-5%; 3=6-10%; 4=11-25%; 5=26-50%; 6=51-75%; 7=76-99%; 8=100%

[y] Means followed by a different letter are significantly ($P=0.05$) different according to Fisher's LSD

[z] Discreteness of the data preclude ANOVA

Visual assessment of leaf damage (Table 3) showed that there was significantly less damage on the Sulphur (Plate 1a), Lime-sulphur (Plate 1b) and Bayfidan treated plots than on the control. At harvest the percentage of leaflets with powdery mildew infection and sporulation (Table 4a) was significantly lower on the sulphur treatment compared to the systemic and control treatments. This is probaly because contact fungicides, such as sulphur and Lime-sulphur, exert their fungicidal action at the surface of the leaf by hindering or preventing germination of spores which alight on them (preventative action), whereas systemic fungicides are designed to arrest fungal growth already within the leaf (curative action).

While the latter fungicides could not prevent initial infection some of them were able to suppress further development of the fungus. Table 4b shows that half as much of the leaf area was infected with powdery mildew on the systemic treatments, Saprol and Tilt (6-10%) compared to the control (11-25%).

The data also shows that the percentage of leaflets with sporulation was only approximately a third of the total leaflets infected (Table 4a). Of these leaflets, only 6-10% of the leaflet area was covered with spores (Table 4b).

TABLE 4a. Percentage of Leaflets with Powdery Mildew Infection and Sporulation at Harvest at Timmering - Site 4

Treatment	% of Leaflets	
	Infection	Sporulation[y]
Sulphur	54 a[w]	6(1) a
Lime-sulphur	76 b	17(9) ab
Saprol	90 bc	27(20) bc
Tilt	89 bc	33(30) bc
Bayfidan	85 bc	32(29) bc
Calixin	94 c	35(32) bc
Control	98 c	36(35) c

TABLE 4b. Leaflet area rating of Powdery Mildew Infection and Sporulation at Harvest at Timmering - Site 4

Treatment	Leaflet area rating[x]	
	Infection	Sporulation[z]
Sulphur	1.2 a[w]	0.69(2.0) ab
Lime-sulphur	1.6 ab	0.14(1.2) a
Saprol	2.3 bc	0.62(1.9) ab
Tilt	2.1 bc	0.67(2.0) ab
Bayfidan	2.5 bcd	0.89(2.4) b
Calixin	2.6 cd	0.51(1.7) ab
Control	3.2 d	0.74(2.1) ab

[w] Means in the same column followed by a different letter are significantly (P=0.05) different.

[x] On 0-5 disease scale: 0=no disease; 1=1-5%; 2=6-10%; 3=11-25%; 4=26-50%; 5=>50% powdery mildew infect./spor.

[y] Angular transformed means with backtransformed means in brackets.

[z] Log transformed means with backtransformed means in brackets.

There was no significant difference in yields, fruit weight and soluble solids between the fungicide and control treatments (Table 5). Although there was a trend for lower percentage soluble solids in the control compared to the fungicide treatments (Tables 2,5). Since the crop did not become severely infected until close to harvest and the weather was mild during that period the amount of sunburnt fruit was negligible.

TABLE 5. Effect of fungicides for control of powdery mildew on yield and quality of harvested tomatoes at Timmering-Site 4

Treatment	Yield (t/ha)		Fruit Weight (g)	Soluble Solids (%)
	Ripe	Green & Rotten		
Sulphur	56	14	37	5.2
Lime-sulphur	67	9	39	5.3
Saprol	44	18	38	5.1
Tilt	68	12	40	5.1
Bayfidan	75	16	43	4.8
Calixin	72	12	40	4.9
Control	69	12	41	4.8
LSD (P=0.05)	30	8	ns	ns

ns = not significantly different

DISCUSSION

Sulphur applied early in disease development is more effective in controlling powdery mildew than systemics. However, if sulphur is applied too late or irregularly there is a risk the crop may become infected since it is essentially a preventative rather than curative spray.

But even despite early and regular applications of sulphur, some growers last season still found their crops became infected with powdery mildew. Insufficient rates of application and/or uneven coverage could explain this. Sulphur may not be as effective towards the end of the season, when there is a higher level of disease pressure, since crops protected early in the season only became infected towards harvest. Higher rates of sulphur may be required at this stage. Aerial application may not give as even coverage of sulphur as ground coverage. Evidence for this is seen where initial breakouts occur around trees.

L. taurica, the powdery mildew which is widespread in the tomato growing areas of California has been identified on capsicums in the Swan Hill area. Research in California has found that systemics are more effective than contact fungicides at controlling this pathogen, possibly because *L. taurica* grows mostly within the leaf unlike the powdery mildew here which grows mostly on the surface. If the *L. taurica* species of powdery mildew was to spread onto tomatoes in Australia current control measures may not be affective against it.

These problems highlight the need for additional investigation to improve the effectiveness of sulphur and to evaluate a range of systemic fungicides for use as a backup control measure in crops where sulphur fails to prevent infection. Currently there is no systemic fungicide registered for use against powdery mildew on tomatoes in Australia.

ACKNOWLEDGEMENTS

The co-operation of growers and supply of chemicals used in the fungicide trials from Bayer, Ciba Geigy, Hoechst and Shell is gratefully acknowledged. We also wish to thank Bill Ashcroft and his field and technical staff for their assistance throughout the season.

PLATE 1a. Sulphur 3.5kg/ha and untreated control plots at harvest (site 4)

PLATE 1b. Lime-sulphur 1L/100L and untreated control plots at harvest (site 4)

PLATE 2a. Tomato leaves infected with powdery mildew

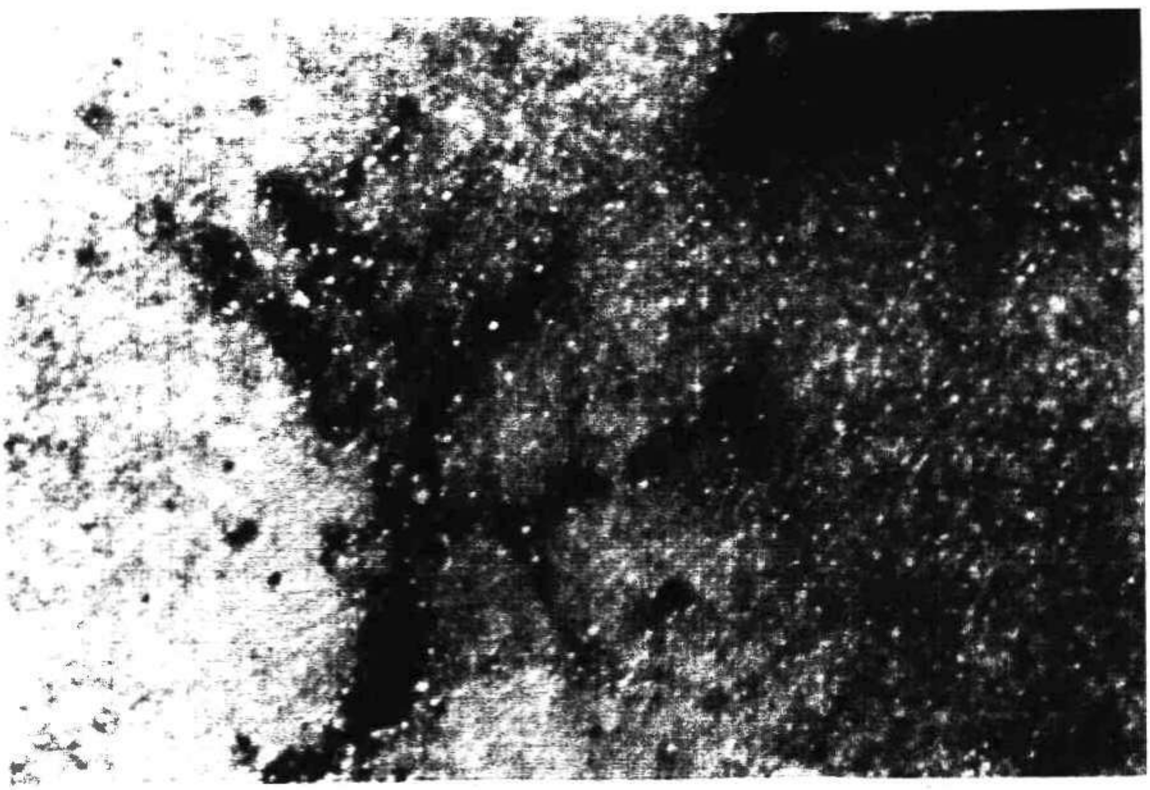

PLATE 2b. Spider-like (arachnoid) symptom caused by powdery mildew