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RESEARCH NOTES

Control of Benomyl Resistant Strains of Green Mould of Citrus with Sodium Ortho-Phenylphenate, 2-Aminobutane and Imazalil

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Citrus packing houses depend heavily upon fungicides for effective post-harvest control of green and blue mould (*Penicillium digitatum* Sacc. and *P. italicum* Wehmer). Sodium ortho-phenylphenate (SOPP) is recommended for control (8) but has been replaced in most Australian packing houses, by recommended benzimidazole derived fungicides. Packing line equipment has been changed accordingly. Larger and more expensive equipment, larger volumes of water for SOPP dips than for benzimidazole suspensions, the need for accurate control of concentration and pH, some risk of fruit burn, large volumes of clean water to rinse SOPP from fruit and some difficulties at the time in getting supplies were the main reasons for SOPP losing favour.

However, fungal resistance to benzimidazole derivatives has been reported in both Australia (9, 13) and overseas (5, 6, 12). Thus the industry requires fungicides which are effective against mould strains resistant to benzimidazole derived fungicides, are chemically unrelated, and which can be used with existing equipment. One such chemical, 2-aminobutane (sec-Butylamine, 2-AB) meets these requirements (3, 12) and has been tested under Australian conditions (11), but is not registered for use in Australia. 2-AB is water soluble and therefore should have some advantages over wettable powder formulations like the benzimidazoles, for post-harvest treatments.

Another fungicide, imazalil, has been evaluated in France (7) and Israel (5). This paper reports on the effectiveness of imazalil in two trials conducted at the Gosford Horticultural Postharvest Laboratory.

The first trial in 1973 looked at the effectiveness of imazalil in controlling benomyl susceptible strains of *P. digitatum,* at a time when resistance had not been reported. When green mould resistance was reported in 1975 (13), the chemical was again evaluated for its effectiveness in controlling a resistant strain of the fungus.

Washington navel and Valencia oranges from the Gosford district were used in trials 1 and 2 respectively. In both trials the fruit was artificially wound inoculated (8, 10) with spores of *P. digitatum* and then loosely packed in open wooden boxes. Spores from sensitive and resistant strains of *P. digitatum* were used in trials 1 and 2 respectively. After 24 hours at ambient temperatures trial 1 fruit was randomly distributed into nine treatment units and trial 2 fruit into 14 units, each unit consisting of about 40 fruits. The treatments shown in tables 1 and 2 were then applied to fruit in trials 1 and 2 respectively, using one unit per treatment. There were four replicates of each treatment.

The imazalil was used as a suspension of the nitrate prepared from a 20% w/v emulsifiable concentrate of imazalil nitrate (R23-979), and as a solution of the sulphate, prepared from technical grade 95% imazalil sulphate, (R27-180) (Janssen Pharmaceutica, Belgium). The 2-AB solution was prepared from Tutane (R), 26% 2-aminobutane carbonated equivalent to 15.45% 2-aminobutane (Elanco Products Company, U.S.A.).

The treated fruit was held for five days at 23°C and then examined for mould wastage. The number of diseased fruits in each treatment unit showing typical mould infection from the inoculation points was recorded and expressed as a percentage of the number of fruit in the unit.

Table 1. Percentage of diseased fruits in Washington navel oranges inoculated with a benomyl susceptible strain of *Penicillium digitatum*, dipped in several fungicides and assessed five days after treatment.

Fungicide treatment	Green mould Diseased fruit(%)
Untreated-30 sec water only dip	98.7
TBZ-5 mg/litre 30 sec dip	84.9
TBZ-25 mg/litre 30 sec dip	6.3
TBZ-125 mg/litre 30 sec dip	0.4
TBZ-625 mg/litre 30 sec dip	0
R23-979 nitrate-5 mg/litre 30 sec dip	46.7
R23-979 nitrate-25 mg/litre 30 sec dip	0.3
R23-979 nitrate-125 mg/litre 30 sec dip	0
R23-979 nitrate-625 mg/litre 30 sec dip	0

Results of the two trials are presented in tables 1 and 2. The efficacy of imazalil nitrate at the low concentration of 25 mg/litre in controlling a susceptible strain of *P. digitatum* is well demonstrated in trial 1. The benomyl resistance of the organism in trial 2 is shown by the 93.8 per cent level of mould wastage in fruit dipped in the benomyl suspension. The effectiveness of SOPP and 2-AB in controlling a resistant strain is confirmed, whilst the effectiveness of imazalil sulphate and nitrate in doing this also is well demonstrated at a concentration of 125 mg/litre which is less than those used elsewhere (5, 7). There was no significant difference in effectiveness between the two forms of imazalil.

Imazalil sulphate would seem to have the same advantages over SOPP and benzimidazoles as does 2-AB, whilst the nitrate has these advantages also, except the one of solubility. Should packinghouse operators in Australia be reluctant to revert to the use of SOPP, 2-AB could eventually become an alternative to the benzimidazoles for post-harvest control of mould in citrus. For similar reasons imazalil might also satisfy the requirements of an alternative.

The likelihood of resistance to imazalil developing is something which would be useful to foresee. Other than it is a systemic compound, the authors are not aware if other factors exist which might relate to this likelihood, such as specific mode of action — whether or not imazalil acts on relatively few metabolic sites, a phenomenon associated with modern fungicides (1, 2, 4). Studies are in progress in the United States and Netherlands to examine the mode of action of imazalil (Janssen Pharmaceutica, private communication).

Imazalil needs evaluation for its residual effects over periods of storage longer than a few days, such as export storage times, which can be up to 10 weeks duration from Australia. Work is also necessary on larger laboratory and commercial scales to establish the behaviour of the chemical when used to treat large quantities of fruit under our packinghouse conditions.

Table 2. Percentage of diseased fruits in Valencia oranges inoculated with a benomyl resistant strain of *Penicillium digitatum*, dipped in several fungicides and assessed five days after treatment.

Fungicide treatment	Green mould Diseased fruit(%)
Untreated-30 sec water only dip	97.3 a
Benomyl-250 mg/l 30 sec dip	94.6 a
SOPP-2% 2 min dip, rinse	2.8 bc
2-AB-1% 30 sec dip	2.8 bc
R27-180 sulphate- 25 mg/l 30 sec dip	51.9 g
R27-180 sulphate-50 mg/l 30 sec dip	22.0 df
R27-180 sulphate-75 mg/l 30 sec dip	13.3 def
R27-180 sulphate-100 mg/l 30 sec dip	7.6 cd
R27-180 sulphate-125 mg/l 30 sec dip	2.6 b
R23-979 nitrate-25 mg/l 30 sec dip	48.8 g
R23-979 nitrate-50 mg/l 30 sec dip	17.9 ef
R23-979 nitrate-75 mg/l 30 sec dip	14.3 def
R23-979 nitrate-100 mg/l 30 sec dip	10.1 de
R23-979 nitrate-125 mg/l 30 sec dip	1.9 b

All values are means of four replicates
Means followed by the same letter do not differ significantly, (P=0.05)

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Aerial Survey of Eyespot Lodging of Wheat in Southern New South Wales

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Eyespot lodging of wheat, caused by the fungus *Pseudocercosporella herpotrichoides* (Fron) Deighton, was first identified in New South Wales by Butler (1), who suggested that ". . .the disease will not constitute a major problem under local conditions." Notwithstanding Butler's statement, we observed lodging associated with the organism in serious proportions in many wheat crops throughout the higher rainfall districts of the southern part of the wheat belt during the wet seasons 1973-75. Discussions with district agronomists and farmers indicated that heavy losses were incurred from these outbreaks.

It was therefore decided to survey the extent and distribution of lodging over a wide area.

On 20th November 1975, when wheat crops were still green but about to senesce, a reconnaissance flight in a light aircraft was conducted. Observations were made in the early morning (7 - 10 a.m.) because the oblique sunrays cast shadows from erect parts of the crop and so facilitated photographic records. The survey established that lodging is readily observable from a height lower than 300 m, with 100 m being about optimum.

Percentage lodging was estimated in randomly chosen paddocks over the flight path shown in Figure 1. Results of these observations are summarised in Table 1. Individual estimates varied from 0% to as high as 90% of the crop lodged.

Table 1. An estimation of the degree of lodging in wheat crops in southern New South Wales by aerial survey.

Degree of Lodging	Crops Surveyed	
	(No.)	(%)
Nil to trace (0-5% lodged)	61	48
Mild to Moderate (6-25% lodged)	36	29
Severe (more than 25% lodged)	29	23

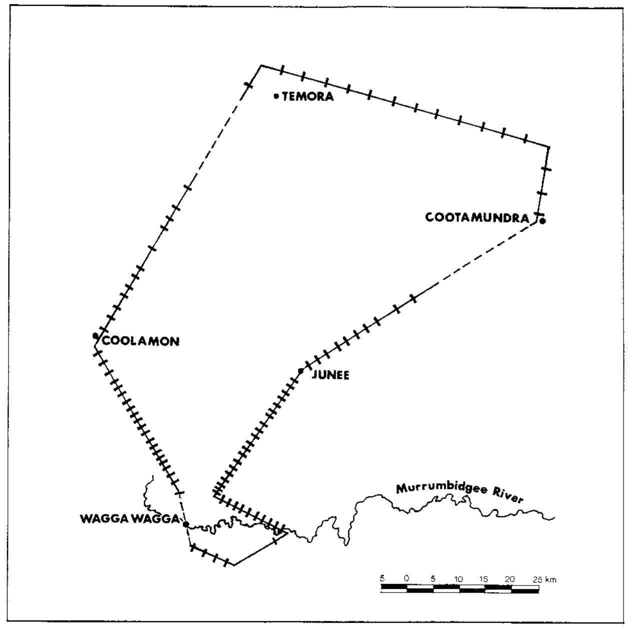

Figure 1 — Route followed in the aerial survey. Closeness of the bars reflects the incidence of lodged crops along the flight path. Broken lines indicate a substantial absence of wheat in the area traversed.

Patches of lodging were often elongated, suggesting spread of the fungus by cultivation, probably through mycelium in stubble from a previous season's infection. Lodging was also frequently associated with headlands. Certain regular patterns of distribution within paddocks suggested the influence of some past cultural treatment. This supports the view that soil condition, soil fertility and crop density affect the intensity of the disease (2).

To confirm that lodging was caused by *P. herpotrichoides*, and not due to physical factors, 20 lodged wheat crops along the flight path were closely inspected on the ground. In all cases, lodging was found to be caused by the pathogen. Where lodging was extensive, the crop still green, and the heads incompletely filled, total losses were experienced.

Losses caused by *P. herpotrichoides* have been determined in New Zealand by Risk and Close (4). Yield increased from 2,400 to 3,420 kg per ha when the pathogen was controlled with a 0.14 kg per ha Benlate spray applied at stage 8 of the Feeke's Scale. Factors contributing to losses are described by Kuiper (3).

We conclude that *P. herpotrichoides* has caused considerable losses in wheat crops in southern New South Wales in seasons favouring its development, and that an aerial survey is an ideal means for determining its extent and distribution.

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