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TOBACCO BLUE MOULD (PERONOSPORA TABACINA ADAM) IN NORTH QUEENSLAND. 4. FUNGICIDE TIME AND METHOD OF APPLICATION EXPERIMENTS

By R. G. O'BRIEN, B.Agr.Sc.

SUMMARY

Similar standards of blue mould control were achieved when bisdithiocarbamate fungicides were applied as mists (8 gal/ac), as medium-volume sprays (90 gal/ac) or as high-volume sprays (180 gal/ac). The protection afforded by fungicidal dusts was inadequate during weather conducive to the disease.

Various criteria were used as guides for the timing of fungicide applications. None of these was as effective as the standard weekly treatment.

Chemical analyses and quality appraisals of cured leaf from these trials failed to detect any consistent differences due to fungicide application.

I. INTRODUCTION

Investigations into the problem of control of blue mould (*Peronospora tabacina* Adam) in tobacco in North Queensland by the use of fungicides have been conducted over several years (Pont 1959; Pont and O'Brien 1967).

Seedling screening and field trials have shown fungicides of the bisdithiocarbamate group to be superior to other chemicals tested. In field trials, satisfactory levels of blue mould control have been achieved when fungicides were applied by high-volume sprays at weekly intervals. The use of high-volume spray application, however, presents some practical problems to growers, particularly with regard to the volume of water used. These could be overcome to a large extent by other techniques of fungicide application.

It is usual with high-volume application for the foliage to be wet to the point of run-off. The technique of low-volume application as described by Courshee, Amsden and Morris (1957) involves using very small volumes of liquid in such a way that discrete droplet patterns are obvious on the foliage

after drying. Medium-volume applications as described by the same authors are regarded as those which result in a considerable proportion of the spray droplets coalescing on the leaf surface without causing run-off. Both these techniques result in a considerable reduction in the volumes of liquid applied.

Fungicidal dusting has been used successfully in some crops. The active ingredient is diluted with a suitable finely divided carrier and taken to the plant surface by an air stream. This method has the advantages of ease of handling and lower cost in terms of time and labour (Martin 1964).

Work reported previously (Pont and O'Brien 1967) on the evaluation of these methods of applying fungicides for blue mould control during the 1964-65 season indicated that misting and high-volume spraying were superior to medium-volume spraying and dusting.

An interval of 1 week between successive spray applications has proved to be a reliable schedule on which to base a disease control programme in the Mareeba-Dimbulah district. Evidence from epidemiological surveys suggests that in some years a reduction in the number of fungicide applications necessary to maintain an adequate control of the disease could be obtained by the use of a suitable spray warning system. Pont and Hughes (1961) found that, although blue mould could spread in the absence of rain, epiphytotics of the disease were dependent upon rainfall for their development. It was suggested, therefore, that a spray warning system based upon rainfall might be successful in this district.

Other workers have formulated criteria to be used as spray warning systems. Cruickshank (1958, 1961) determined the critical conditions of temperature and humidity for sporulation of *P. tabacina* under laboratory conditions. These findings were shown to apply under field conditions and were suggested as a basis for a blue mould forecasting and spray warning service (Rider, Cruickshank and Bradley 1961).

Paddick (1964) improved the performance of this spray warning system by altering the humidity standard.

An important requirement of a blue mould fungicide is that it should not have an adverse influence on the quality of cured tobacco. European workers (DeBaets 1963; Mickovski 1963) have reported small changes in some chemical constituents due to the application of maneb and zineb. The organoleptic properties of treated tobacco on the other hand were virtually unchanged (DeBaets 1962).

The results of taint testing, chemical analyses and physical appraisal of cured leaf reported by Pont and O'Brien (1967) indicated that the bisdithiocarbamate fungicides did not affect physical leaf quality or chemical constituents. Tainting was not induced provided fungicide application ceased 7-10 days before harvest.

This paper describes further trials conducted in North Queensland investigating the control of blue mould of tobacco. Several methods of applying fungicides and several criteria used as spray warning systems are evaluated. Work carried out to detect any effect which fungicides might have on leaf quality is also presented.

II. MATERIALS AND METHODS

Trials were conducted annually at the Parada Research Station, North Queensland, during three seasons commencing in 1965 and continuing until 1967.

The flue-cured variety Hicks was used in all trials. Fungicide applications commenced 7-10 days following transplanting and continued until 7 days before the first harvest.

Fungicide application method.—

(*a*) High-volume spraying: A "Tricrop" spray unit with fixed boom and flexible droppers was used for this treatment. The spray volume varied from approximately 30 gal/ac initially to 180 gal/ac. Spray concentrations were mancozeb 0·16% a.i. and mezineb 0·14% a.i.

(*b*) Medium-volume spraying: This treatment was also applied by a "Tricrop" spray unit. The volume applied was approximately half that used in the high-volume treatment.

(*c*) Misting: A "Moto-blo" knapsack unit applied the fungicide in mist form at the rate of 8 gal/ac. This volume of liquid was kept constant for each application, although the amount of fungicide used was increased to keep pace with the growing crop. A 2-row misting head designed and supplied by H. R. Mapother (Long Ashton Research Station, England) was fitted to the mister. The coverage obtained was tested by fluorescent tracer and found to be very satisfactory.

(*d*) Dusting: Dusts were applied with a "Moto-blo" knapsack mister fitted with a dusting attachment. A 10% fungicide-pyrophyllite dust was used throughout.

Fungicide application criteria.—

(*a*) Weekly application: Fungicides were applied at weekly intervals.

(*b*) Application "after rain": The factors governing fungicide application to this treatment were—

(i) At least 0·01 in. of rainfall to be recorded on a single day.

(ii) The interval between successive applications of fungicide to be at least 3 days.

(*c*) Application "after 0·40 in. rain": For this treatment criteria were—

(i) At least 0·40 in. of rain to be recorded within a period of 3 days.

(ii) The interval between successive applications of fungicide to be at least 3 days.

(*d*) Spore trapping: Fungicides were applied following any sudden increase in spore production as detected by a Hirst 24-hr spore trap.

(*e*) Modified Cruickshank Formula (M.C.F.): Fungicides were applied following a critical temperature-humidity period—i.e. when a night during which the relative humidity exceeded 85% for a minimum continuous period of 3 hr followed a day during which temperatures were in excess of 30°C for not more than 6 hr (Paddick 1964).

Experimental layout and treatments.—In the 1965-66 and 1966-67 trials a randomized block layout of 7 treatments replicated four times was employed. The 1967-68 trial was also of randomized block design consisting of six treatments replicated four times. Each plot comprised three 66 ft rows and was separated from neighbouring plots by four unsprayed guard rows. Disease ratings were made on the central row of each plot. Quality assessments were carried out on harvested leaf from the whole plot.

The treatments used in each trial are shown in Tables 2–4. Mancozeb was the fungicide used in the 1965-66 trial and mezineb in the 1966-67 and 1967-68 trials.

In the first two trials, fungicide application was made by misting machine to those treatments not subjected to a regular weekly schedule. The dosage at which either fungicide was applied at any particular time by any method during the course of a trial was standardized on the dosage applied by high-volume spraying at that time.

In 1967-68, the misting machine was used to apply fungicides to all treatments, whenever application was necessary. Dosages were determined by the schedule in Table 1.

TABLE 1

FUNGICIDE DOSAGE RATES, 1967–68

Time after Transplanting (weeks)	Quantity of fungicide/acre (oz a.i.)	
	Mancozeb	Mezineb
1–3	8·0	7·0
4	12·8	11·2
5	25·6	22·4
6	38·4	33·6
7	44·8	39·2
8	44·8	39·2
9	44·8	39·2

Disease assessment.—Field ratings were made shortly before the first harvest. Assessments were made on two criteria:

(*a*) A whole plant percentage index of infection was derived for 10 plants in each plot. This was obtained by appraising the amount of damage (expressed as percentage leaf area destroyed) on each leaf and then calculating a mean figure for each plant.

(*b*) In order to gauge the effect on yield, any leaf with 40% or more of its lamina covered by blue mould was considered as lost because it undoubtedly would not have been harvested and cured. A mean figure for the number of leaves lost per plant or the percentage of leaves lost per plant was calculated for each plot.

Quality assessment.—

(*a*) Quality Index: Leaf was harvested, cured and placed in bulk storage for a period of 2–3 months. It was then sorted into bundles of similar type, weighed and graded, using a points system which takes into account the physical characteristics of colour, pliability, grain and maturity. Points were allocated according to the following scale:

Colour	0–50
Pliability	0–10
Grain	0–10
Maturity	0–30
TOTAL	0–100

The Quality Index of each plot was derived from the formula:

$$\text{Quality Index} = \Sigma \frac{(\text{bundle quality x bundle weight})}{\text{Whole plot weight}}$$

(*b*) Chemical analysis: Samples of cured tobacco (cutter and leaf positions) from the 1965-66 trial were analysed for chemical constituents such as chlorides, potassium, nitrogen, manganese, alkaloids and sugars.

III. RESULTS

(a) Blue Mould Incidence

(i) *1965-66 trial*—Blue mould was not apparent in the trial block until late in the season. High temperatures and an absence of overcast weather resulted in a low disease incidence when the trial was rated prior to the first harvest. Two fungicide applications were made to the "after rain" treatment but none were made to the "after 0·40 in. rain" treatment. The results are shown in Table 2.

TABLE 2

1965–66 TRIAL: BLUE MOULD INCIDENCE (MEAN VALUES)

Treatment	No. of Fungicide Applications	Whole Plant Infection Index	No. of Leaves Lost per Plant
A. Misting weekly	7	0·52	0
B. Dusting weekly	7	0·53	0
C. Medium-volume spraying weekly ..	7	0·66	0
D. High-volume spraying weekly ..	7	0·35	0
E. After rain	2	1·16	0
F. After 0·40 in. rain	0	4·27	0·45
G. Untreated	0	3·14	0·32
S.E. of treatment means	..	0·88	..
Necessary differences for significance ..	.. 5%	2·61	..
	.. 1%	3·58	..
		F ⩾ A, B, C, D F > E G > A, D	

The generally low disease incidence does not allow a very satisfactory comparison of the different treatments. All application methods were equally efficient. Some benefit was obtained from the two "after rain" applications.

TABLE 3

1966–67 TRIAL: BLUE MOULD INCIDENCE

Treatment	No. of Fungicide Applications	Whole Plant Infection Index		Percentage Leaves Lost per Plant	
		*Trans. Mean	Equiv. Mean	*Trans. Mean	Equiv. Mean
A. Misting weekly	7	0·324	10·14	0·194	3·71
B. Dusting weekly	7	0·596	31·51	0·640	35·68
C. Medium-volume spraying weekly	7	0·270	7·11	0·075	0·56
D. High-volume spraying weekly ..	7	0·283	7·79	0·070	0·49
E. After rain	3	0·284	7·86	0·176	3·07
F. After 0·40 in. rain	2	0·299	8·67	0·175	3·03
G. Untreated	0	0·596	31·51	0·608	32·66
S.E. of treatment means ..	..	0·043		0·064	
Necessary differences for significance	5%	0·128		0·190	
	1%	0·176		0·261	
		B, G ⩾ A, C, D, E, F		B, G ⩾ A, C, D, E, F,	

* Inverse sine transformation used for analysis.

(ii) *1966-67 trial*—The incidence of blue mould was light until a period of showery weather in November. The crop at this stage had been planted in the field 8 weeks and was nearing maturity. A very rapid build-up of blue mould occurred in the trial area during and after the favourable weather period. Plants in the unsprayed guard rows and untreated plots were severely affected, many leaves showing sporulation over the entire dorsal and ventral surfaces.

The results in Table 3 clearly show that the protection afforded by the weekly dusting treatment was markedly inferior to that given by any other weekly application method.

No significant differences could be detected between other weekly application treatments. A remarkably good control of blue mould was obtained by the fungicide applications applied "after 0·40 in. rain" and "after rain".

(iii) *1967-68 trial*—Blue mould appeared in the trial area soon after transplanting and spread slowly in the absence of rain in the following weeks. The disease was thus well established prior to a rain group which occurred in October. Following this period, blue mould built up to high levels in all plots except those which received weekly fungicide applications. The results are shown in Table 4.

TABLE 4

1967–68 TRIAL: BLUE MOULD INCIDENCE

Treatment	Number of Fungicide Applications	Whole Plant Infection Index		Number of Leaves Lost per Plant	
		*Trans. Mean	Equiv. Mean	†Trans. Mean	Equiv. Mean
A. Application weekly	8	0·196	3·80	0·756	0·07
B. Application after rain	3	0·447	18·69	2·043	3·67
C. Application after 0·40 in. rain ..	2	0·469	20·46	2·195	4·32
D. Application according to spore trapping	1	0·478	21·15	2·246	4·54
E. Application according to M.C.F.	5	0·388	14·29	1·624	2·14
F. Untreated	0	0·487	21·90	2·299	4·79
S.E. of treatment means ..	..	0·029		0·202	
Necessary differences for significance	5%	0·087		0·609	
	1%	0·120		0·842	
		B, C, D, E, F, ⩾ A D, F, > E		B, C, D, E, F, ⩾ A D, F, > E	

* Inverse sine transformation used for analysis.

† Square root $(x + \frac{1}{2})$ transformation used for analysis.

Five fungicide applications made according to the Modified Cruickshank Formula lowered the incidence of blue mould slightly.

(b) Leaf Quality

The results of leaf quality determinations by physical appraisal are summarized in Table 5.

TABLE 5

1966–67, 1967–68 TRIALS: LEAF QUALITY INDEX FOR DIFFERENT SPRAY SCHEDULES

Treatment	Leaf Quality Index	
	1966–67	1967–68
Misting weekly	43·0	41·7
Dusting weekly	40·5	..
Medium-volume spraying weekly ..	44·1	..
High-volume spraying weekly ..	46·1	..
After rain	43·6	38·5
After 0·40 in. rain	43·4	40·0
Spore trapping	..	39·1
Modified Cruickshank Formula ..	..	39·1
Untreated	43·2	38·9

Chemical analyses of samples from the 1965-66 trial did not reveal any consistent differences between mancozeb-treated and untreated leaf with regard to percentage chlorine, potassium, total alkaloids, reducing sugars and nitrogen. There was an increase in manganese content in samples from the cutter position of the misting treatment. A similar increase did not occur in samples from the leaf positions of the same treatment nor from samples from other treatments which received identical quantities of fungicide.

IV. DISCUSSION

In this series of trials, misting, medium-volume and high-volume spraying gave good control of blue mould. There were indications that although fungicidal dusts performed satisfactorily under conditions of low inoculum potential, the protection afforded by this method rapidly diminished when the inoculum potential was increased. The dependence of epiphytotic outbreaks of blue mould in North Queensland on showery weather suggests that the inefficiency of dusts may have been due to a comparatively poor weathering ability during these periods. This was noted by Burchfield (1960), who stated that particles or aggregates of particles in the size range of dusts are easily dislodged by wind and rain.

Other workers have reported both success and failure with fungicidal dusts in controlling blue mould. Hitier, Mounat and Michel (1965) found dusting to be more efficient than spraying, while Rui (1963) found the converse to be true.

The success of misting and medium-volume spraying as application techniques in these trials demonstrates that, where equivalent quantities of fungicide are used, the success of the protection programme depends not so much on the quantity of liquid carrier as on the ability of the equipment to give a satisfactory distribution on the surfaces to be protected. In the trial reported earlier (Pont and O'Brien 1967), the dosage applied to the medium-volume spray treatment was half that applied to the high-volume treatment and the blue mould control was inferior. In the trials under discussion, equivalent dosage rates with both high and medium volume were applied and similar standards of blue mould control were obtained.

It must be emphasized that misting in these trials was carried out by means of a knapsack unit which was found to give a good distribution of fungicide over all leaf surfaces. It is unlikely that similar results could be expected with fixed outlet units which do not give this standard of distribution.

The application of fungicides "after rain" or "after 0·40 in. rain" under North Queensland conditions may prevent mass outbreaks of disease following suitable weather periods in crops where blue mould is not well established prior to the onset of the favourable weather period. The use of these criteria in crops where the disease is well established and distributed prior to receiving rainfall has produced disappointing results. Application schedules based on these criteria cannot therefore be recommended to growers.

The Modified Cruickshank Formula and spore trapping were included as spray warning criteria in only one trial; the results compared unfavourably with those obtained by weekly fungicide application.

The physical appraisal of leaf from all trials discussed in this paper did not reveal any consistent differences that could be attributed to the application of fungicides by any of the methods employed.

It was noticed that the fungicidal deposit on misted leaves was more tenacious and more evident after curing than it was on leaves which had received other treatments. It is possible, therefore, that the increases in manganese content of leaf associated with misting were due to higher external manganese rather than to an absorption of this element by leaf tissue.

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REFERENCES

BURCHFIELD, H. P. (1960).—*In* "Plant Pathology", Vol. 3, Ch. 12. (Academic Press: New York).

COURSHEE, R. J., AMSDEN, R. C., and MORRIS, H. J. (1957).—Report to the Government Entomologist, Sudan, 1957 (unpublished). Cited by Evans, E. (1967) Biological appraisal of spraying techniques for foliar fungicides. *Wld Crops* 19(2):10-11.

CRUICKSHANK, I. A. M. (1958).—Environment and sporulation in phytopathogenic fungi I. Moisture in relation to the production and discharge of conidia of *Peronospora tabacina* Adam. *Aust. J. biol. Sci.* 11:162-70.

CRUICKSHANK, I. A. M. (1961).—Environment and sporulation in phytopathogenic fungi II. Conidia formation in *Peronospora tabacina* Adam as a function of temperature. *Aust. J. biol. Sci.* 14:198-207.

DEBAETS, A. (1962).—Hebben behandelingen met carbamaten invloed op de kwaliteit van droge tabak? (Do the dithiocarbamates influence the quality of the treated tobacco?) *Ghent. Landbhogesch. Meded.* 27(3):1148-63. (Abstract in *Tob. Abstr.* 7:362).

DEBAETS, A. (1963).—Is tobacco quality affected by carbamates? II. *Ghent. Landbhogesch. Meded.* 28:910-22. (Abstract in *Tob. Abstr.* 8:426).

HITIER, H., MOUNAT, A., and MICHEL, E. (1965).—Tests with anti-blue mould fungicides in 1964. *Ann. Dir. Etud. Equip., Serv. Exploit. ind. Tabacs. Allum., Sect.* 2., 2:99-106 (In *Rev. Appl. Mycol.* 47:624).

MARTIN, H. (1964).—"The Scientific Principles of Crop Protection". 5th Ed. (Edward Arnold: London).

MICKOVSKI, J. (1963).—Efficacy of some chemicals for controlling *Peronospora tabacina* Adam. *Proc. 3rd Wld Tob. Sci. Congr.* Theme 1:149-58.

PADDICK, R. G. (1964).—Comparison of spray warning systems for control of blue mould of tobacco in the field. *Proc.* 1964 *Aust. Tob. Res. Conf.*: 270-6.

PONT, W. (1959).—Blue mould (*Peronospora tabacina* Adam) of tobacco in North Queensland. Some aspects of chemical control. *Qd J. agric. Sci.* 16:299-327.

PONT, W., and HUGHES, I. K. (1961).—Tobacco blue mould (*Peronospora tabacina* Adam) in North Queensland. 2. Epidemiological studies bearing on the development and control of the disease. *Qd J. agric. Sci.* 18:1-31.

PONT, W. and O'BRIEN, R. G. (1967).—Tobacco blue mould (*Peronospora tabacina* Adam) in North Queensland. 3. Fungicide screening and efficacy experiments. *Qd J. agric. Anim. Sci.* 24:187-200.

RIDER, N. E., CRUICKSHANK, I. A. M., and BRADLEY, E. F. (1961).—Environment and sporulation in phytopathogenic fungi III. *Peronospora tabacina* Adam. Field environment, sporulation and forecasting. *Aust. J. agric. Res.* 12:1119-25.

RUI, D. (1963).—The influence of carriers and diluents on the efficacy of non-cupric anti-*Peronospora* fungicidal dusts. *Tobacco, Roma* 47(709):192-201 (In *Rev. Appl. Mycol.* 43:2725).

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The author is an officer of Plant Pathology Branch, Queensland Department of Primary Industries, and is stationed at Mareeba.