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Effect of 6-azauracil against apple powdery mildew and apple scab

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Abstract

In 1964 and 1965 trials were made with 6-azauracil (AzU) against powdery mildew and scab in an apple orchard at Kloetinge (Zeeland) and at Wageningen. The activity against scab was moderate, but against powdery mildew the results were better than those obtained with Karathane. The activity against mildew is ascribed to the systemic action of AzU, which protected shoots not hit by the spray, as well as those developing after the treatment. Sprays with AzU also reduced the overwintering of powdery mildew in the terminal buds. When concentrations of 100 and 50 ppm were used, the young shoots developing were often malformed, but even with lower concentrations, still active against mildew, the trees were not completely free of slight abnormalities.

Introduction

Apple powdery mildew, caused by the fungus *Podosphaera leucotricha* (Ell. et Ev.) Salm, is a serious disease in the fruit growing areas of The Netherlands. The frequency of infection periods (Roosje and Besemer, 1965) makes it difficult to obtain complete control. Susceptible young leaves, developing after application of a protective spray remain unprotected until application of the following spray. This makes it worthwhile to look for systemic compounds, capable of protecting also unsprayed parts and new growth. As 6-azauracil (AzU), an antimetabolite of the RNA base uracil, had shown systemic action against various other powdery mildews (Dekker and Oort, 1964; Dekker and van den Hoek-Scheuer, 1964), this chemical was tested against apple powdery mildew. A preliminary report on the effect of AzU against apple powdery mildew has been published by Oort and Dekker (1964).
Since inorganic sulphur compounds for the control of apple scab caused by *Venturia inaequalis* (Cke.) Wint., and apple powdery mildew were replaced largely by organic fungicides it became common practice in The Netherlands to apply a mixture of an organic fungicide against apple scab and another against apple powdery mildew. This has resulted in a considerable increase in the cost of spraying against apple scab and mildew. A new chemical effective against scab and mildew, but without harmful effects on the crop, would therefore be welcomed.

Materials

Technical AzU was kindly prepared by the Organic Chemical Institute T.N.O. at Utrecht, The Netherlands. In 1965 a wettable powder was used, formulated by N.V. Philips-Duphar at Amsterdam, which had the following composition: 50% technical AzU, 35% aluminium silicates, 5% stabiliser and 10% wetting and dispersing agents, A sticker was added to the suspension of the wettable powder in water.

Results

Preliminary experiments in 1962 and 1963

In 1962 five healthy shoots on 'Yellow Transparent' trees at Wageningen were sprayed weekly with an AzU solution, starting on 24 May. Five healthy control shoots were sprayed with water. On all control shoots a more or less heavy powdery mildew infection occurred, whereas the AzU-treated shoots remained almost free from powdery mildew. In 1963, when more of the chemical became available, two 'Yellow Transparent' and two 'Jonathan' trees were sprayed weekly with 25 ppm. AzU, starting 31 May and ending in the beginning of September. An equal number of control trees remained unsprayed. A count made at the end of July on 50 shoots of the treated 'Yellow Transparent' trees revealed only 12 leaves with a trace of powdery mildew, as against 114 leaves showing slight to severe infection on the control trees. For the 'Jonathan' trees these figures were 17 and 246, respectively. At the same time it was noted that there was a very marked reduction of apple scab on the AzU-treated trees. Fifty shoots per tree were evaluated, using a scale from 0 for no scab to 5 for severe scab infection. The average scab index on AzU-treated 'Yellow Transparent' trees was 0.8, compared with 2.5 on the control trees. For the 'Jonathan' trees these figures were 0.4 and 3.1, respectively. The apples from the 'Jonathan trees' were harvested in October; 58% of the apples from the AzU-treated trees were free from scab and 1.3% of the apples from the control trees.

In 1963 AzU was also sprayed on potted apple rootstocks (MM 111), 24 and 72h before inoculation with mildew, to compare with 25 ppm Karathane WP (= 6.25 ppm dinocap) according to a technique described elsewhere (Roosje, 1963). In this experiment 100 ppm AzU was less effective against apple mildew than 6.25 ppm dinocap. In two other experiments on potted rootstocks 100 ppm AzU applied 48h *after* inoculation was again less effective in suppression of mildew than dinocap. It is suggested that the discrepancy between the disappointing results of single applications of AzU and the promising results of weekly applications may be related to the mode of action of AzU.

The preliminary results in 1962 and 1963 warranted a further investigation of AzU as a systemic agent for control of powdery mildew and scab on apples. In the two following years experiments were therefore carried out in the orchard of the Laboratory of Phytopathology at Wageningen and in a commercial orchard at Kloetinge, in the South West of The Netherlands.

Fields trials in 1964

In the orchard at Kloetinge the effect of AzU against apple powdery mildew was compared with that of a standard treatment with 0.1% Karathane (active ingredient dino-

Table 1. Effect of AzU on powdery mildew of apples, cv. 'Jonathan', in orchard at Kloetinge. Application at 9–12 day intervals from 5 May until 17 August 1964.

Treatment	*% of infected leaves*			*% of leaf underside covered with mildew*		
	June 3–6	*July 7–10*	*August 24–26*	*June 3–6*	*July 7–10*	*August 24–26*
Control (untreated)	91.1	98.5	99.3	22.4	31.6	39.1
Dinocap 250ppm + captan	52.6	59.3	69.7	4.7	6.4	9.2
AzU 50ppm	47.7	19.1	15.9	5.3	1.3	1.1
AzU 100ppm*	33.1	7.5	7.2	2.9	0.5	0.5

* When phytotoxic effects became visible, the concentration was decreased to 25 ppm

Tabel 1. Effect van AzU tegen meeldauw op appel, cv. 'Jonathan', in een boomgaard te Kloetinge. Bespuitingen om de 9–12 dagen vanaf 5 mei tot 17 augustus 1964.

cap, 250 ppm) and 0.2% Orthocide 50 (active ingredient captan, 1000 ppm). Per treatment there were eleven trees, divided in three groups of two or three trees each. The groups were separated by untreated guard trees. Eleven sprays were given between 5 May and 17 August at intervals of 9–12 days. Evaluation of powdery mildew was made between 3 and 6 June, between 7 and 10 July and finally between 24 and 26 August. Per treatment, 500 leaves on 100 shoots were examined. Of each leaf-underside the percentage of the area covered with powdery mildew was estimated (Table 1). It appears that in the beginning the effect of 50 ppm AzU was comparable to that of dinocap, but that later a marked difference became visible. On the diconap-treated trees the amount of powdery mildew increased progressively during the course of the season, but on the AzU-treated trees it decreased considerably.

These phenomena occurred also in a small experiment with 'Jonathan' trees at Wageningen, although to a lesser extent. Here 4 trees were sprayed with 50 ppm AzU, 2 trees with dinocap 150 ppm and 2 trees with captan 1000 ppm; 4 trees served as a control. Further, the two trees that had been sprayed with 25 ppm in the preceding year,

Table 2. Effect of AzU on powdery mildew of apples, cv. 'Jonathan', in orchard at Wageningen. Application weekly from 13 May until 26 August 1964.

Treatment	*% of infected leaves*			*% of leaf underside covered with mildew*		
	June 10	*July 21*	*August 26*	*June 10*	*July 21*	*August 26*
Control (untreated)	52.5	74.1	90.3	7.5	21.7	22.6
Dinocap 250ppm	7.7	20.3	30.0	0.5	1.8	3.2
AzU 50ppm	8.8	8.9	5.5	0.5	0.5	0.3
AzU 25ppm*	3.0	4.5	2.1	0.2	0.3	0.2

* Also sprayed in the preceding year with 25 ppm AzU

Tabel 2. Effect van AzU tegen meeldauw op appel, cv. 'Jonathan', in een boomgaard te Wageningen. Bespuitingen wekelijks van 13 mei tot 26 augustus 1964.

Table 3. Effect of AzU on apple scab, in orchard at Wageningen, cv. 'Jonathan'. Application weekly from 13 May until 26 August. Evaluation on 14 August 1964.

Treatment	*% of infected leaves*	*% of leaf underside covered with scab*
Control (untreated)	68.3	10.6
Captan 0.2%	10.3	0.6
AzU 50 ppm	1.8	0.1
AzU 25 ppm*	1.0	0.05

* Also sprayed in the preceding year with 25 ppm AzU

Tabel 3. Effect van AzU tegen appelschurft, cv. 'Jonathan', in boomgaard te Wageningen. Bespuitingen wekelijks van 13 mei tot 26 augustus. Beoordeling op 14 augustus 1964.

were again sprayed in the same way. Treatments were carried out weekly, starting on 13 May. Evaluation of powdery mildew was carried out at three dates (Table 2), and evaluation of scab on 13 August (Table 3). It appears that both powdery mildew and scab are suppressed considerably by the AzU treatments. Especially in the trees treated for the second year, the occurrence of powdery mildew was negligible.
Phytotoxicity symptoms, however, became visible in all AzU treatments, at Kloetinge

Fig. 1. Serious malformation of shoot in apple tree, cv. 'Jonathan', sprayed at 9–12 day intervals with 100 ppm 6-azauracil (left). Orchard at Kloetinge, 1964.

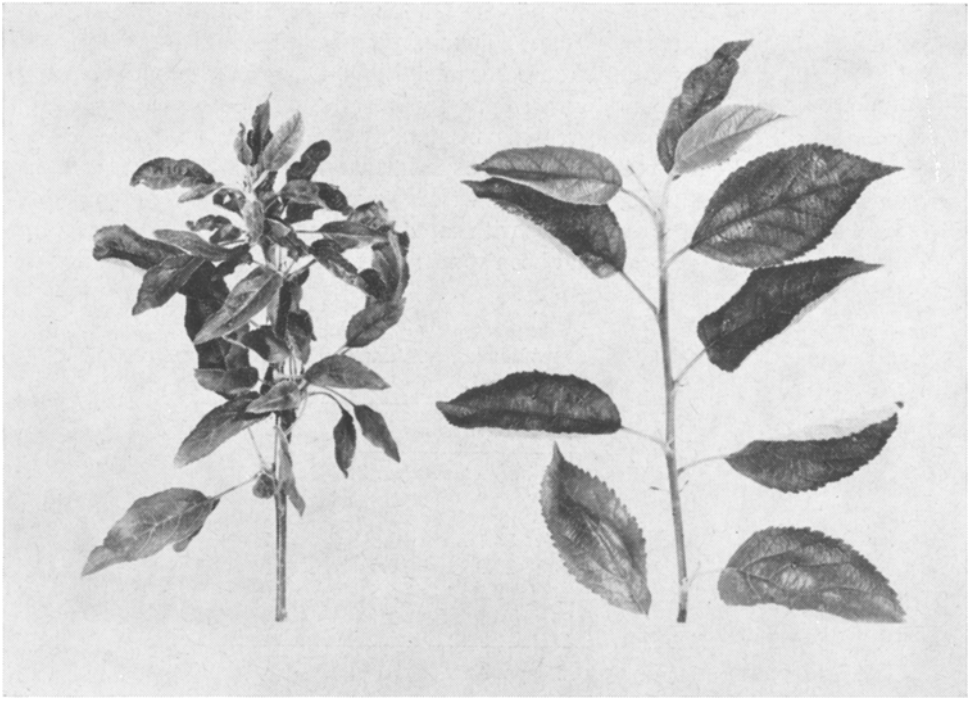

Fig. 1. Ernstige misvorming van scheut in appelboom, cv. 'Jonathan', die om de 9–12 dagen bespoten werd met 100 ppm 6-azauracil (links). Boomgaard te Kloetinge, 1964.

as well as at Wageningen. They were most pronounced in the 100 ppm AzU treatment. Malformed young shoots developed during the course of the season; these shoots remained very short and showed a marked proliferation (Fig. 1). The leaves were smaller and lighter coloured than those of untreated trees. These symptoms occurred to a lesser extent also in the trees treated with 50 ppm AzU, and even at 25 ppm slight abnormalities appeared. When the fruits were harvested an evaluation of the russeting was made. The percentages of apples showing russeting in the field trial at Kloetinge were 66 in the control, 44 for dinocap, 65 for AzU 50 ppm, and 76 for AzU 100 ppm. This suggests that russeting may have been increased somewhat by AzU treatment. The trees sprayed in 1964, were inspected during the spring of 1965 in order to see whether there was any after effect of the AzU treatment. It appeared that the number of fruit buds was considerably reduced in the trees sprayed with 100 ppm, and to a limited extent in the trees sprayed with 50 ppm AzU. Because of the toxic side effects of the AzU treatment, it was decided to carry out experiments with lower dosages of AzU in 1965.

Field trial in 1965

In the orchard at Kloetinge apple trees, cv. 'Jonathan' and cv. 'Golden Delicious', were treated with formulated AzU in the following way:

S.(standard treatment): 0.1% Karathane (= 150 ppm active ingredient dinocap) + 0.15% Orthocide 83 (= 1245 ppm active ingredient captan) 10–12 days intervals, total of 11 sprays.

A. 12.5 ppm AzU at 10–12 day intervals, total of 11 sprays.

B. 12.5 ppm AzU, the first four sprays at intervals of 10–12 days, later sprays at intervals of 20–22 days: total of 7 sprays.

C. 25 ppm AzU, the first four times at intervals of 10–12 days, thereafter at intervals of 20–22 days; total of 7 sprays.

D. the first four sprays 12.5 ppm AzU, later sprays 6.25 ppm all at intervals of 10–12 days; total of 11 sprays.

E. untreated.

Per treatment there were three one-tree plots, separated from each other by untreated guard trees. Evaluation of the powdery mildew on the 'Jonathan trees' was carried out

Table 4. Effect of AzU on powdery mildew of apple, cv. 'Jonathan', in orchard at Kloetinge, 1965

*Treatment**	*% of infected leaves*		*% of leaf underside covered with powdery mildew*	
	June 23	*July 20*	*June 23*	*July 20*
S: dinocap + captan	48.3	73.3	6.0	13.1
A: AzU 12.5ppm	59.2	60.6	9.8	8.0
B: AzU 12.5ppm	74.4	79.0	13.6	15.1
C: AzU 25ppm	58.1	42.1	8.3	4.2
D: AzU 12.5; 6.25ppm	73.1	79.6	13.4	15.8
E: untreated	93.5	98.5	25.4	51.6

* For spray intervals and for concentrations of dinocap and captan see text

Tabel 4. Effect van AzU tegen appelmeeldauw, cv. 'Jonathan', in boomgaard te Kloetinge, 1965

Table 5. Effect of AzU against apple scab, cv. 'Jonathan' and 'Golden Delicious', in orchard at Kloetinge, 1965

*Treatment**	*Percentage of fruits with scab*	
	Jonathan	*Golden Delicious*
S: dinocap + captan	0.1	0.3
A: AzU 12.5ppm	1.8	8.0
B: AzU 12.5ppm	4.1	14.6
C: AzU 25ppm	0.5	8.4
D: AzU 12.5; 6.25ppm	0.7	7.4
E: untreated	4.1	21.7

* For spray intervals and for concentrations dinocap and captan see text

Tabel 5. Effect van AzU tegen appelschurft, cv. 'Jonathan' en Golden Delicious', in boomgaard te Kloetinge, 1965

on 23 June and 20 July, and on the 'Golden Delicious' trees between 17 and 22 June, on 21 July, and on 24 August.

The results on 'Jonathan' (Table 4) show, as would be expected that the effect of AzU against powdery mildew decreases with lower concentrations and with longer spray intervals. The effect of AzU 12.5 ppm every 10–12 days is in the end more or less comparable to that of dinocap. The results on 'Golden Delicious' appeared to be similar to those obtained on 'Jonathan'. Some phytotoxicity was observed on 20 july in the trees of both varieties sprayed with 25 ppm AzU, and on 24 August even in the trees treated with 12.5 ppm every 10–12 days. From these experiments it was concluded that not enough margin is available between the fungitoxic and phytotoxic concentration to warrant practical application.

In the same experiment an evaluation was made of the development of scab (Table 5). Although a clear effect was obtained against scab, the results obtained at these concentrations were not satisfactory enough to warrant the use of AzU for commercial scab control.

Table 6. Overwintering of powdery mildew in apple trees, cv. 'Jonathan', at Kloetinge, sprayed with AzU in 1964 at 9–12 day intervals from 5 May until 17 August. Assessment of 1000 terminal buds and shoots in spring 1965.

Treatment	*Distorted terminal buds*	*Shoots with overwintered powdery mildew*
	March 29, 1965	*May 13, 1965*
Control (untreated)	959	284
Dinocap 250ppm	443	315
AzU 50ppm	258	30
AzU 100ppm	332	12

Tabel 6. Overwintering van meeldauw in appelbomen, cv. 'Jonathan', te Kloetinge, die om de 9–12 dagen bespoten waren met 6-azauracil vanaf 5 mei tot 17 augustus in 1964. Beoordeling van 1000 eindknoppen en scheuten in het voorjaar van 1965.

Overwintering

In the spring of 1964 and 1965 observations were made on the overwintering of powdery mildew in trees sprayed with AzU in the preceding season. In the two 'Jonathan' trees at Wageningen, which were sprayed with 25 ppm AzU in 1963, no shoots with overwintering mildew emerged in the spring of 1964, against 81 in two unsprayed control trees. In the spring of 1965 a strong reduction of overwintered mildew was observed in trees sprayed with AzU in 1964 (Table 6). The finding that the number of shoots with overwintered mildew on trees untreated in the previous season was lower than on the trees sprayed with dinocap is misleading, for on the untreated trees many buds were so badly infected that they were killed.

Discussion

At concentrations of 25 ppm and higher, with spray intervals of 7–12 days, the control of powdery mildew by AzU is better than that obtained by the standard treatment with dinocap. It is presumed that the superior effect of AzU is due to its systemic action, providing protection also for leaves developing after a treatment. This was first demonstrated for cucumber powdery mildew and later also for apple powdery mildew. Apple seedlings were sprayed with a 100 ppm solution of AzU, except for the four top leaves. After 48 or 72 h conidia were dusted on these plants in an inoculation tower (Roosje, 1963). On the top leaves that had not been exposed to the AzU spray the powdery mildew infection was reduced to 26% and 10% of the controls, respectively. In the orchard this protection of unsprayed leaves might perhaps be even better since the concentration of the chemical or its derivatives might build up to higher levels after repeated sprayings.

It has been shown earlier that the action of AzU on fungi is due to its conversion to 6-azauridine-5′-phosphate (AzUMP) (Dekker, 1967). The latter compound is an inhibitor of orotidine-5′-phosphate decarboxylase, an enzyme involved in the synthesis of pyrimidines. Since it appears that the apple plant, also is able to convert AzU into the toxic AzUMP, phytotoxicity of AzU could be expected, especially in young, rapidly growing parts of the plant, where RNA synthesis is active. The observations, made in the trials here reported, are in agreement with this. It may be concluded, however, that AzU inhibits the development of powdery mildew more strongly and more rapidly than it inhibits growth of the plant. Some considerations about the selective action of AzU have been given by Dekker (1968). Unfortunately, as shown by the trials described in this paper, the selectivity of AzU is not sufficient to warrant commercial use.

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Samenvatting

Effect van 6-azauracil tegen meeldauw en schurft op appel

In 1964 en 1965 zijn in een boomgaard te Kloetinge (Zeeland) en te Wageningen enige proeven genomen met 6-azauracil (AzU) ter bestrijding van meeldauw en schurft op appel. De activiteit tegen schurft was matig (Tabel 3 en 5), maar die tegen meeldauw was beter dan de werking van Karathane (Tabel 1, 2 en 4). Dit laatste wordt toegeschreven aan de systemische werking van AzU, waardoor ook niet geraakte en op het moment van bespuiting nog niet uitgegroeide scheuten beschermd worden. Bespuitingen met 6-azauracil reduceerden ook de overwintering van meeldauw in de eindknoppen (Tabel 6). Bij concentraties AzU van 100 en 50 ppm ontwikkelden zich scheuten met misvormingen (Fig. 1), maar ook de bomen die met lagere concentraties behandeld waren, bleven niet geheel vrij van lichte afwijkingen.

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