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Preharvest and Postharvest Applications of Benzimidazoles for Control of Storage Decay of Pears[1]

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Abstract. **Two orchard sprays with 800 ppm methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate (benomyl) or three orchard sprays with 300 ppm 2-(4-thiazolyl) benzimidazole (thiabendazole or TBZ) achieved significant control of storage decay of 'Spadona' pears (*Pyrus communis* L.). Almost complete control of storage decay required postharvest dip-treatments of 1000 ppm benomyl or 500 ppm TBZ. *Penicillium expansum* and *Botrytis cinerea* (Pers. ex Fr.) were inhibited by these treatments but *Alternaria tenuis* (Nees ex Cda.) was unaffected and its incidence increased during storage, possibly due to control of the other organisms. These benzimidazole treatments tended to increase the incidence of internal breakdown of treated pears during prolonged regular cold storage.**

'Spadona', the principal pear grown in Israel, is attacked during storage mainly by *Penicillium expansum* and *Botrytis cinerea* and, to a lesser degree, by *Alternaria tenuis. Penicillium expansum* and *B. cinerea* can be effectively controlled on various fruit crops by postharvest dips with TBZ or benomyl (1, 2, 3, 5). Since both these systemic fungicides are being examined in Israel to control *Venturia pyrina* Aderh. in pear orchards, we thought that these applications might reduce postharvest fruit decay. The effects of weekly or fortnightly sprays throughout the growing season were compared therefore with a few preharvest sprays and with postharvest dips.

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Orchard-treatments. Orchard A: Trees were sprayed with benomyl weekly during the 10 weeks preceding harvest. The experimental design consisted of 2 random blocks with 6 trees per replicate.

Orchard B: Trees were sprayed 12 or 6 times with benomyl from the emergence of leaf-buds until 3 weeks before harvest. The control consisted of regular sprays with 0.25% captan (N -trichloromethylthio - 4 - cyclohexene - 1, 2-dicarboximide) (50% wettable powder). The experimental design consisted of random blocks, each treatment being applied in 4 replicates of 6 trees each.

Preharvest sprays were applied in 2 orchards. In orchard C, 3 blocks of trees (6 trees per treatment) were sprayed 3 times - 2 weeks, 1 week and 1 day prior to harvest, with 3 concn of benomyl. In orchard D, 6 blocks of trees were sprayed thrice (1, 7, and 14 days), twice (1 and 7 days) and once (1 day before harvest) with either TBZ or benomyl.

All harvested fruit was handled under commercial conditions, including passage over a packing line. For each treatment a random sample of 10 replicates of 50 fruits each was wrapped and packed in polyethylene liners. The fruit was stored at $-1^{O}C$ and examined upon removal from storage and after 3 days' shelf-life at room temp.

Postharvest treatments. Postharvest dips with benomyl and TBZ were applied to noninoculated and to artificially inoculated fruit. The latter fruit were punctured and dipped into a suspension containing 10^5 spores of *P. expansum*/ml and 10^6 spores of *B. cinerea*/ml at ca. $25^{O}C$. The fruit was treated with the fungicidal solutions the day following inoculation and was then packed and stored as described above. Each treatment consisted of 5 replicates of 50 fruits each.

In a preliminary trial with artificially inoculated fruit held at $20^{O}C$, 300 and 500 ppm TBZ inhibited development of *P. expansum* and *B. cinerea* respectively, and 300 ppm benomyl inhibited both fungi (Fig. 1). In the treated fruits that had been infected by these fungi, the duration of the incubation period (i.e. till the first signs of decay were visible) was extended, but the rate of rot development thereafter was not affected. The increased development of *P. expansum* on fruit treated with 500 ppm TBZ compared to 300 ppm, may have been due to phytoxicity. This effect was also noticed after prolonged treatment at concn above 100 ppm (Table 1). Whereas the prolonged dip reduced *B. cinerea* development at all concn, the development of *P. expansum*, which is facilitated for example in senescent fruit, increased after prolonged treatment in 300 and 500 ppm TBZ. Frequent orchard sprays with benomyl effectively reduced the incidence of storage decay caused by *P. expansum* and *B. cinerea* (Table 2). When these fungi were the principal agents of decay, the reduction in storage rot was highly significant, but when *A. tenuis* was the chief decay organism, its incidence increased, likely due to inhibition of rot development caused by *P. expansum* and *B. cinerea.* Three preharvest sprays were no less effective than the frequent sprays in controlling these 2 fungi, and the lowest benomyl concn applied (400 ppm) was sufficient to reduce total rot incidence from 35.6% to 0.7%. A single spray, applied 1 day prior to harvest, reduced storage rot incidence but was not as effective as 2 or 3 sprays applied during the 2 weeks prior to harvest.

Postharvest dips of 500 ppm TBZ or 1000 ppm benomyl effectively controlled decay of artificially inoculated and orchard-infected 'Spadena' pears during 18 weeks of

Table 1. The effect of the duration of postharvest thiabendazole dip treatments on rot development in 'Spadona' pears inoculated with *P. expansum* and *B. cinerea* (3 weeks' storage at 20°C).

	Rot development (%)			
	P. expansum		*B. cinerea*	
TBZ concn	Duration of dip (min)			
(ppm)	1	3	1	3
100	45	27	75	70
300	16	32	50	10
500	32	45	0	0

storage at −1°C and 3 days of shelf-life at ambient temp (ca. 20°C) (Table 3 and Fig. 2). With TBZ the % decay caused by *P. expansum* and *B. cinerea* was generally proportional to the dosage. Benomyl at 1000 ppm was almost as effective as at 3000 ppm in controlling the development of both fungi, in spite of the differences shown in Fig. 1. Probably a lower concn than 1000 ppm benomyl might be effective commercially. The increased effectiveness of 3000 ppm compared to 1000 and 2000 ppm benomyl on *P. expansum* noticed with inoculated fruit (Fig. 1) could relate to the high concn of inoculum under such conditions.

Satisfactory rot control was obtained by preharvest sprays and by postharvest dips with either benomyl or TBZ. However, since harvested fruit is always treated with a scald-preventative, such as "Stop-Scald" (ethoxyquin), which was combined with the above fungicides (Table 3) (3, 4), application of preharvest orchard sprays to only control storage decay seems superfluous.

There were 2 disadvantages to pre- and postharvest treatment of fruit which, however, did not outweigh the advantage obtained by the extent of decay control. First, the increased incidence of *A. tenuis* observed in some of the preharvest treatments, was also apparent in inoculated, treated fruit, even though the inoculum did not contain spores of this fungus (Fig. 2). In orchards where this fungus is the predominant rot-causing organism, an increased incidence of decay might result during storage. Second, incidence of internal breakdown of pears significantly increased after prolonged cold storage in some experiments, due to prior treatment with TBZ or benomyl. Three benomyl sprays applied during the 2 weeks before harvest, induced a significant rise in the

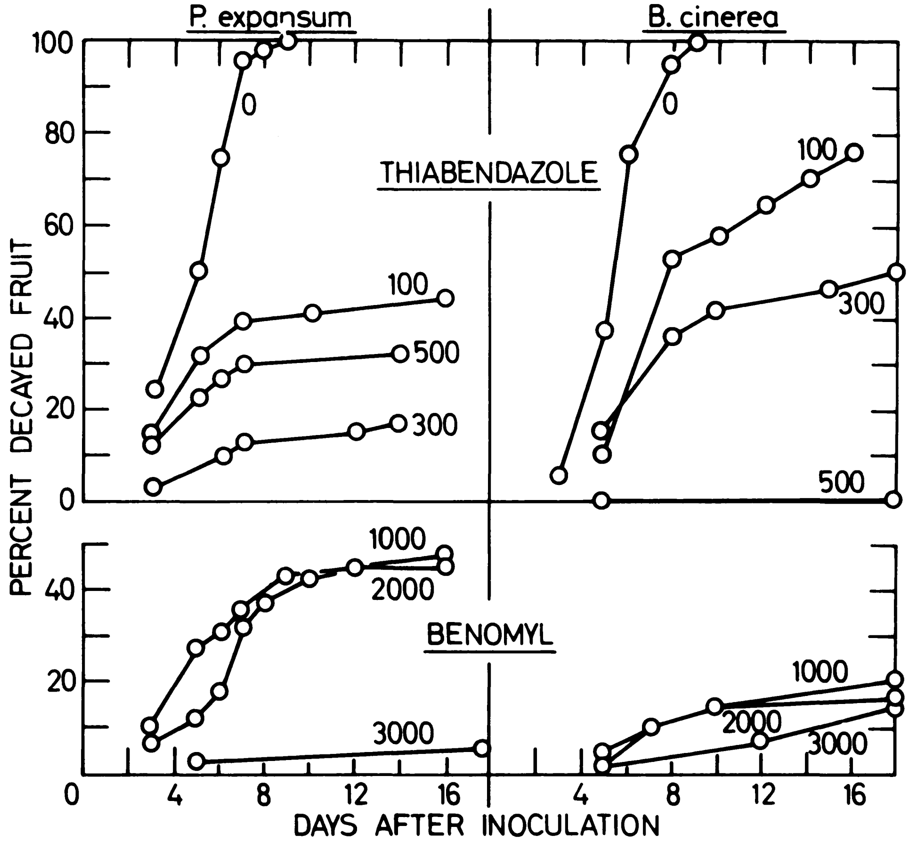

Fig. 1. The effects of thiabendazole and of benomyl on the length of the incubation period, and the development of decay at 20°C on 'Spadona' pears inoculated with *P. expansum* or *B. cinerea.* Fruit were considered decayed at the first visible signs of rot.

Table 2. The effect of orchard sprays with benomyl and TBZ on the incidence of decay of 'Spadona' pears during storage at −1°C.

Orchard	Treatment (ppm)	No. of applications[z]	Duration of storage (weeks)	Decay (%) *P. expansum*	*B. cinerea*	*A. tenuis*	Total
A	None	–	16	10	0	30.2	40.2
	Benomyl (250)	10		0**	0	45.5	45.5
	" (500)	10		0**	0	57.2*	57.2*
B	None	–	24	9.1	0	0	9.1
	Benomyl (250)	12		0**	0	2.1	2.1**
	" (500)	6		0**	0	0.2	0.2**
C	None	–	21	35.6	0	0	35.6
	Benomyl (400)	3		0**	0	0.7	0.7**
	" (800)	3		0**	0	0.7	0.7**
	" (1200)	3		0**	0	1.7	1.7**
D	None	–	24	17.2	8.0	1.4	26.6
	Benomyl (800)	1		2.3**	0.**	2.0	4.3**
		2		3.6**	2.0**	1.1	6.7**
		3		0.4**	0.4**	1.1	1.9**
	TBZ (300)	1		17.0	0**	2.3	19.3
		2		12.6*	0**	0.7	13.3*
		3		8.2**	0.8**	1.5	10.5**

* Differs from control, 5% level.
** Differs from control, 1% level.
z For time of spray applications, see text.

Table 3. The effect of postharvest benomyl and TBZ dips on % decayed 'Spadona' pears, (18 weeks' storage at $-1^{o}C$ plus 3 days shelf-life at ambient temp).

Treatment (ppm)	Decay (%) *P. expansum*	*B. cinerea*	*A. tenuis*
None	10.0	5.4	2.5
Benomyl (1000)	0	0.4	1.5
" (2000)	0.1	0.4	1.3
" (3000)	0	0	0.4
" (") + 1500 ppm "Stop Scald"[z]	0.2	0.4	1.3
Thiabendazole (100)	10.5	2.8	0.4
" (300)	3.6	0.8	2.3
" (500)	1.2	0.4	1.6
" (") + 1500 ppm "Stop Scald"[z]	0	0.4	1.0
LSD 1%	2.7	2.1	N.S.

[z]The "Stop Scald" was added to the fungicidal suspension. In other treatments the fruit was treated with "Stop-Scald" approx 30 min before the fungicidal treatment' "Stop-Scald"dip alone or "Stop-Scald" plus fungicide dips lasted 30 sec whereas the other fungicidal dips lasted 1 min.

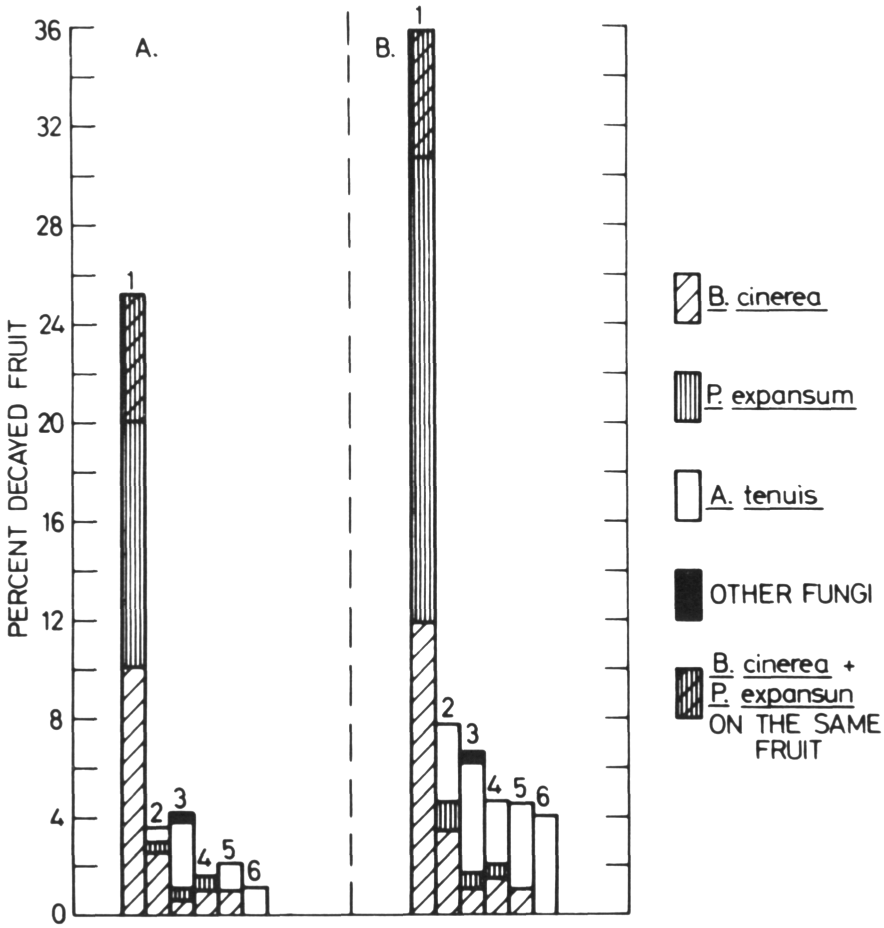

Fig. 2. The effects of TBZ and of benomyl on the development of decay on 'Spadona' pears inoculated with *P. expansum* and *B. cinerea*.
A. After 18 weeks' storage at $-1^{o}C$.
B. After 18 weeks' storage at $-1^{o}C$ plus 3 days at ambient temp.
1. Control
2. TBZ 300 ppm
3. TBZ 500 ppm
4. TBZ 800 ppm
5. Benomyl 1000 ppm
6. Benomyl 3000 ppm
All treatments were combined with 900 ppm "Stop-Scald."

Table 4. The effect of preharvest benomyl sprays on internal breakdown of 'Spadona' pears. (21 weeks' storage at $-1^{o}C$).

Treatment (ppm)	Internal breakdown (%)
None	1.7
Benomyl (400)	6.1**
" (800)	4.8**
" (1200)	8.6**

**Differs from control, 1% level.

Table 5. The effect of postharvest dip treatments with benomyl and TBZ on the internal breakdown of 'Spadona' pears. (18 weeks' storage at $-1^{o}C$ and 3 days' shelf-life at ambient temp).

Treatment (ppm)	Internal breakdown (%)
None	24.7
Benomyl (1000)	52.7
" (2000)	42.1
" (3000)	48.3
TBZ (100)	44.1
" (300)	39.2
" (500)	41.0
LSD 1%	13.4

incidence of internal breakdown (Table 4), whereas a larger no. of applications throughout the season, but terminated 3 weeks before harvest (orchards A and B), had no such effect. (In these experiments no internal breakdown occurred in the control either.) There was also a tendency to increased internal breakdown when the no. of preharvest TBZ sprays was increased from 1 to 3, but the level of incidence was generally low and the differences insignificant. Postharvest dips of pears also significantly increased internal breakdown in 1 trial (Table 5). However, there was no dose-dependence in the severity of the disorder in this case, and dipping for 3 min did not further increase its incidence. This effect of benzimidazole treatment has not been reported for other pear cultivars, but it should be kept in mind, if the storage life of treated fruit is expected to be extended.

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