Cultivar Differences in Response to Triadimenol Seed Treatment for Control of Barley Net Blotch Caused by *Pyrenophora teres*

J. EDMUND SHERIDAN, Plant Pathologist, and NICK GRBAVAC, Graduate Research Assistant, Botany Department, Victoria University of Wellington, Wellington, New Zealand

ABSTRACT

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In the spring of 1981, there was an upsurge of net blotch, caused by *Pyrenophora teres*, in commercial barley crops in the North Island of New Zealand. In the following season, net blotch became epidemic in the Manawatu/Wanganui districts. This was believed to be due to the failure of the popular seed treatment containing triadimenol + fuberidazole to control the disease on the newly introduced cultivars Mata and Triumph. Trials confirmed the poor performance of triadimenol on these and other new cultivars and its continued effectiveness on the older cultivar Zephyr. In the autumn of 1984, triadimenol also failed to control net blotch on Zephyr. The problem appears to have arisen from the introduction of a triadimenol-insensitive fungus on overseas cultivars.

Net blotch of barley is caused by the seedborne fungus *Pyrenophora teres* Drechs. (conidial state *Drechslera teres* (Sacc.) Shoem.) (Figs. 1 and 2). Widespread outbreaks with high yield losses occurred in New Zealand crops after the withdrawal of the organomercury seed treatments in the early 1970s. The new systemics, 20% carboxin + 20% thiram (Vitaflo 200) and 15% carbendazim + 60% mancozeb (Granosan 200), were introduced in the 1977–1978 season and 15% triadimenol + 2% fuberidazole (Baytan F17) was introduced in the 1979–1980 season (4). Net blotch became of little significance (2). In the 1981–1982 season, there was an upsurge of net blotch in barley crops in the North Island of New Zealand followed by an epidemic in the Manawatu/Wanganui districts in 1982–1983 (6). This was believed to be due to the failure of the popular seed treatment containing triadimenol to control the disease on the newly introduced cultivars Mata and Triumph. Trial results supported this belief (5). The three registered seed treatments were introduced on the basis of superior performance on cultivars Zephyr and Carlsberg (3,4). With the introduction of many new cultivars, Carlsberg has disappeared from commerce and Zephyr has decreased in popularity. In July 1983, a new seed treatment containing imazalil (Fungazil) was registered with the Pesticides Board.

Present address of second author: Plant Health and Diagnostic Station, Ministry of Agriculture and Fisheries, Levin, New Zealand.

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This paper reviews the evidence for cultivar differences in response to triadimenol and discusses possible reasons for its failure to control net blotch on the newly introduced barley cultivars in New Zealand.

MATERIALS AND METHODS

Crop surveys. Commercial barley crops in the Wairarapa and Manawatu/Wanganui districts of the North Island of New Zealand were inspected each year for net blotch infection. Inspections began at Feekes' growth stage 1 (Zadoks 10) to determine primary seedborne infection and continued at intervals until Feekes' growth stage 11.1 (Zadoks 77) to determine disease severity.

Primary infection was assessed by counting the diseased plants in four lots of 25 plants along a diagonal of the field. Primary net blotch symptoms generally consisted of one lesion on the first leaf. Disease severity was assessed on 10 tillers taken at random along a diagonal; the diseased area of the top two leaves was determined using a disease assessment key.

Seed treatment. Seed of all available naturally infected barley cultivars was treated with fungicides. Zephyr was used as a standard cultivar and organomercury (1% mercury as phenyl mercury acetate + ethyl mercury chloride) as a standard seed treatment for comparison.

In laboratory applications, 250 g of seed was placed in a 500-ml conical or round-bottomed flask with the appropriate amount of fungicide. The flask was placed in a wrist-action shaker and 2.5 ml of sterile distilled water was added slowly while shaking. Shaking was continued for 15 min (spring 1978–1983) or 10 min (all other trials), the shorter time being equally effective. Water was omitted from the organomercury and untreated checks. A special procedure was used for treating with imazalil. The fungicide was made up in ethanol by adding 7.14 or 14.28 ml of the 70% concentrate of imazalil to 800 ml of ethanol followed by 200 ml of water, sufficient to treat 100 kg of seed and containing 5 or 10 g a.i. of imazalil, respectively. While seed was being shaken, 2.5 ml of the dilution was added to 250 g of seed. Where infected seed was scarce (autumn 1983 trial), 200 g was treated using the appropriate amount of fungicide. In concrete-mixer treatments, 15 kg of seed was treated each time. In the Mist-O-Matic treatment, carried out by the Canterbury Malting Company, the ethanol contained 0.25% tertiary butanol as a denaturant.

Fig. 1. Primary net blotch infection on barley leaf.

Glasshouse and field trials. In glasshouse trials, 100 seeds from each treatment were sown in sterilized 70% peat/perlite mixture, 20 seeds per 11-cm plastic pot, and grown under conditions conducive to net blotch development. Field trials were carried out in the Wairarapa District of the North Island, which did not have a crop of barley in the previous year. These consisted of both hand-sown and tractor-sown trials using normal farm machinery. All treatments were randomized and replicated. Drills were 5 m long in hand-sown trials and plots were 80 × 2.5 m (concrete mixer) or 175 × 16 m (Mist-O-Matic) in tractor-sown trials.

All diseased and healthy seedlings were counted at Feekes' growth stage 1 in glasshouse and hand-sown field trials. Diseased seedlings were counted in four lots of 25 plants along one (concrete mixer) or two (Mist-O-Matic) diagonals of each plot at Feekes' growth stage 1 or 2 in tractor-sown trials.

Seed infection levels. Seed infection was determined by plating 100 seeds of each cultivar or seed line onto malt-extract agar containing 10 μg/ml of benomyl in plastic petri dishes. Two days after plating, the plates were subjected to near-ultraviolet irradiation for 12 hr each day. Incubation was on the laboratory bench at 18–22 C. Colonies of *D. teres* present after 7 days were counted.

Statistical analyses. All confidence intervals given have a 95% chance of containing the true value being estimated. Where a confidence interval is given for the percentage control, the additional uncertainty due to using an estimated natural infection rate is not allowed for; the intervals are slightly narrower than an exact 95% interval would be.

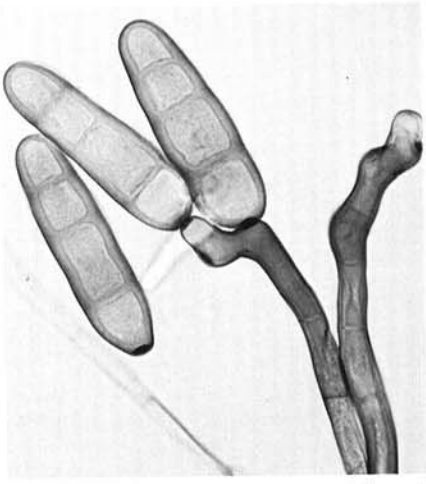

Fig. 2. Conidiophores and conidia of *Drechslera teres* produced in the laboratory. Scale bar = 20 μm.

RESULTS

Crop surveys, 1981–1983. Net blotch built up to an epidemic in the Manawatu/Wanganui districts in the 1982–1983 growing season (Table 1). This was associated with an increase in the area planted to the cultivar Triumph and almost exclusive use of triadimenol + fuberidazole seed treatment. Primary infection was found in all crops inspected of this cultivar. In the following season, a dramatic reduction in net blotch severity occurred with the use of the new seed treatment containing imazalil. Little seedborne infection was found, the main source of inoculum being debris and overwintering volunteer plants. In the Wairarapa District, where Triumph was not grown commercially and the popular seed treatment was carboxin + thiram, most crops were free of net blotch during these years. High levels of inoculum were maintained at our trial site in the Wairarapa District to produce infected seed for subsequent work. Carbendazim + mancozeb was unpopular throughout the country.

Seed treatment trials. *Spring trials, 1982.* The performance of the three registered seed treatments was compared with that of organomercury in glasshouse tests and hand-sown field trials in the Wairarapa District in the spring of 1982. Carboxin + thiram and carbendazim + mancozeb gave good control on all three cultivars (Table 2). Triadimenol + fuberidazole gave good control on Zephyr but significantly less on Mata (less than 35%) and Triumph (less than 45%). Increasing the application rate by 50% had little effect on performance.

In large-plot, tractor-sown trials, where the fungicides were applied by Mist-O-Matic machine or concrete mixer, triadimenol + fuberidazole performed poorly, giving less than 50% control on

Table 1. Data obtained from barley crop surveys in the Manawatu-Wanganui districts of North Island, New Zealand, from 1981 to 1984

	1981–1982	1982–1983	1983–1984
Percentage of crops infected with net blotch	52	100	56
Mean percent diseased area of top two leaves	7.9	12.6	0.5
Percentage of seed (crops) treated with			
20% Carboxin + 20% thiram	0	8	1
15% Triadimenol + 2% fuberidazole	100	92	7
0.625% Imazalil	0	0	92
Percentage of crops planted with			
Triumph	36	82	82
Mata	28	2	0
Georgie	20	5	4
Koru	0	0	9
Zephyr	12	4	0
Others	4	7	5

Table 2. Effects of registered seed treatments applied in the laboratory on net blotch infection in three barley cultivars in spring of 1982 (hand-sown trials)

		Number of seedlings with net blotch					
		Glasshouse[a]			Field[b]		
Treatment	Rate (g a.i./100 kg seed)	Zephyr	Triumph	Mata	Zephyr	Triumph	Mata
Triadimenol + fuberidazole	15 + 2	1	13	10	3	32	26
	22.5 + 3	...	7	6	...	28	22
Carboxin + thiram	50 + 50	1	0	0	3	2	1
	75 + 75	...	0	1	...	4	1
Carbendazim + mancozeb	30 + 120	0	2	0	1	12	2
	45 + 180	...	3	2	...	6	1
Organomercury	2.2	0	0	0	0	0	0
Untreated check	...	10	16	15	54	57	22
Emergence in untreated check[c]		95	100	100	732	696	722
Seedborne infection (%)		92	84	88	92	84	88

[a] Number of seedlings with net blotch infection 21 days after sowing (100 seeds sown).
[b] Mean number of seedlings with net blotch infection 18 days after sowing averaged over five replicates.
[c] Number of seedlings emerged in the glasshouse test (100 seeds sown) and mean number of seedlings emerged averaged over five replicates for the field trial.

Triumph (Table 3). Although control was significant compared with the untreated check, it was significantly poorer than carboxin + thiram or imazalil on Triumph and Mata but not Zephyr. Essentially similar results were obtained in a Mist-O-Matic-treated trial in the Manawatu District. The level of seedborne infection was high in all cultivars. It appeared that triadimenol + fuberidazole was cultivar-specific. The Zephyr seed line came from the Wairarapa District, and the others, from the Manawatu District.

Review of trials, 1978–1983. An examination of the level of net blotch control given by triadimenol + fuberidazole since trials first began indicated consistently good control on cultivar Zephyr from 1978 to 1983 (Table 4). Control on cultivars Mata and Triumph was poor. In 1983, no control was obtained in three seed lines of Triumph. All seed lines of Mata and Triumph came from the Manawatu District, whereas those of Zephyr were obtained from the Wairarapa District. It seemed possible that the source of the seed might influence the response to triadimenol.

Autumn trials, 1983 and 1984. In autumn of 1983 and 1984, all available infected cultivars were treated with triadimenol + fuberidazole and planted in hand-sown trials in the Wairarapa District. Satisfactory control was obtained only on the cultivar Zephyr in the 1983 trial (Table 5). Seed came from various sources and infection ranged from 8% in cultivar Hassan to 84% in cultivar Triumph. In an attempt to produce a consistently high infection level of homogenous inoculum and eliminate locality differences, cultivars for seed to be used in the 1984 trial were grown in plots (100 × 10 m) on the trial site in the Wairarapa District. An epidemic occurred and seedborne infection was high in all cultivars. Triadimenol + fuberidazole gave little control on any cultivar including Zephyr (Table 5). This was the first time this fungicide failed on Zephyr. The same sample of triadimenol + fuberidazole was used as in the previous year. Imazalil performed well on all cultivars in both years.

DISCUSSION

The upsurge in net blotch in commercial barley crops in New Zealand in recent years is attributed to the failure of the triadimenol + fuberidazole seed treatment to control the disease on newly introduced barley cultivars, particularly the popular Triumph. Evidence comes both from crop survey findings and trials. This seed treatment was ineffective on all seed lines of Triumph tested regardless of infection levels, method of application, or locality of the trial. It was also ineffective on 13 other cultivars. It continued, however, to give good control on our lines of cultivar Zephyr in the Wairarapa District until autumn of 1984, when it suddenly failed.

How can the failure of triadimenol in net blotch control in the recently introduced cultivars such as Mata and Triumph be explained, and why has it continued to give good control on Zephyr until now? Is triadimenol cultivar-specific? Has an insensitive race or strain of *P. teres* been introduced with the overseas cultivars or has a new race developed in this country? To answer these questions, it is necessary to consider carefully the changing scene in New Zealand barley growing, particularly with respect to new cultivars (1,6). Carlsberg and Zephyr were introduced from Denmark and Holland in the 1950s and 1960s, respectively, and have been grown continuously in this country although both have now become unpopular. Triadimenol + fuberidazole

Table 3. Effects of registered seed treatments applied by Mist-O-Matic machine or concrete mixer on net blotch infection in three barley cultivars in spring of 1982 (tractor-sown trials)

Treatment	Rate (g a.i./100 kg of seed)	Percentage of seedlings with net blotch[a]			
		Mist-O-Matic	Concrete mixer		
		Triumph	Triumph	Mata	Zephyr
Triadimenol + fuberidazole	15 + 2	(11.3) 13.0 (15.7)[b]	6.7	5.7	(0.1) 0.3 (1.6)
Carboxin + thiram	50 + 50	(0.4) 0.7 (1.4)	0.2	0.3	(0.4) 1.3 (1.6)
Imazalil	10	(0.4) 0.7 (1.4)	0.0	0.0	0.0
Untreated check	...	(17.5) 19.8 (22.8)	12.7	12.3	(11.3) 15.7 (15.9)
Seedborne infection (%)	...	61	90	99	96

[a] Counted 21 days after sowing, five replicates for Mist-O-Matic trial and three for concrete-mixer trial.
[b] Numbers in parentheses are 95% confidence limits (upper and lower limits).

Table 4. Effects of seed-treatment fungicides applied in the laboratory on net blotch control in hand-sown field trials in spring of 1978–1983

Cultivar	Year of trial	Source	Year obtained	Percent seedborne infection	Control as percent of untreated check[a]			Mean no. of seedlings in untreated check[b]	
					Triadimenol + fuberidazole (15 + 2)	Carboxin + thiram (50 + 50)	Imazalil (5)	Emerged	Diseased
Carlsberg	1978	W[c]	1977	90	92	88	...	364	25
Zephyr	1978	W	1977	85	98	94	...	389	40
	1981	W	1981	37	98	79	...	394	11
	1982	W	1982	92	95	95	100	755	54
	1983	W	1983	42	89	100	100	565	2
Mata	1981	M	1981	31	67	81	...	549	27
	1982	M	1982	88	0	95	100	728	23
	1983	M	1983	40	...	92	100	567	3
Triumph	1982	M	1982	84	44	96	100	666	57
	1983	M	1983	47	29	73	100	657	11
		M	1983	42	0	97	100	574	8
		M	1983	56	0	95	100	581	10
		M	1983	61	0	100	100	602	5

[a] All seed treatment fungicides were applied at the recommended rate (given as g a.i./100 kg of seed).
[b] Mean number of seedlings emerged and with net blotch infection counted 18 or 21 days after sowing averaged over five (1978 and 1981) or four replicates (1982 and 1983).
[c] W = Wairarapa, M = Manawatu.

Table 5. Effects of triadimenol and imazalil seed treatments on net blotch infection in 15 barley cultivars in autumn trials in 1983 and 1984

Cultivar	Source and percent seedborne infection[a]		Control as percent of untreated check[b]				Mean no. of seedlings in untreated check[c]			
			Triadimenol + fuberidazole (15 + 2)		Imazalil (5)		Emerged		Diseased	
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984
Aclaim	M 34	W 90	42 (25–65)[d]	8	100	99	552	523	3	28
Georgie	···	W 96	··· ···	31	···	100	···	557	···	77
Goldmarker	···	W 100	··· ···	3	···	100	···	665	···	26
Grit	M 30	W 98	42 (22–62)	9	100	100	546	514	4	33
Hassan	? 8	W 52	100 ···	0	100	100	571	469	1	34
Kaniere	···	W 97	··· ···	0	···	100	···	529	···	41
Koru	? 37	···	44 (32–59)	···	100	···	626	···	8	···
Kym	M 21	···	66 (48–41)	···	100	···	577	···	9	···
Lada	M 67	W 100	50 (43–58)	36	100	100	635	544	54	77
Magnum	? 74	···	85 ···	···	100	···	576	···	9	···
Mata	M 60	W 92	22 (11–32)	0	100	100	560	607	20	64
Maxima	M 62	W 96	32 (20–44)	0	100	100	533	477	12	44
Porter	···	W 97	··· ···	0	···	98	···	637	···	46
Triumph	W 84	W 90	68 (58–76)	5	99	100	535	566	24	67
Zephyr	W 83	W 96	100 (96–100)	23	100	100	602	607	14	104

[a] W = Wairarapa, M = Manawatu.
[b] Seed treatment fungicides were applied at the recommended rate (given as g a.i./ 100 kg of seed).
[c] Emerged = mean number of seedlings emerged averaged over two replicates; diseased = mean number of seedlings with net blotch infection counted 21 days after sowing averaged over four or six replicates in 1983 and three replicates in 1984.
[d] Numbers in parentheses are 95% confidence limits for percent control achieved (lower and upper limits).

was registered with the Pesticides Board in New Zealand in 1979 on the basis of its superior performance in net blotch control on these cultivars. Mata was bred in New Zealand and released in 1975, whereas Triumph was introduced from Britain and released in 1982. Triumph became very popular, making up 90% of all malting barley plantings last season. Total barley plantings increased by 50% and a large export market has opened up. There are now more than 20 barley cultivars in New Zealand, many of which are from Europe.

Before obtaining the results of the autumn 1984 trial, we were uncertain of the reason for the failure of triadimenol and suggested that there may be some blockage of triadimenol uptake in the cultivar Triumph or that the fungicide may be metabolized once inside the seed or seedling (5). Triadimenol appeared to be cultivar-specific. It now seems more likely that insensitivity of *P. teres* to triadimenol is responsible. We believe that an insensitive race or strain was introduced to New Zealand. Because Triumph originated in East Germany, a study of race sensitivity to triadimenol in Europe and Britain may shed further light on the problem. The epidemic in the Manawatu/Wanganui districts, the chief malting barley-growing area of the North Island, in 1982–1983 would ensure high levels of infection with the race or strain carried on Triumph on all cultivars grown there, including Zephyr. The Wairarapa District has been relatively free of net blotch in recent years (6), and the only Triumph crop grown was on our trial site for the first time in 1982–1983. Our seed lines of Zephyr had been grown from untreated seed each season and were grown in the same field with Triumph for the first time in 1982–1983. Triadimenol gave slightly lower than expected control on seed from this crop (89%), but this was not considered significant because of the relatively low infection in the untreated check. In the following year, Zephyr was grown along with 11 other cultivars, including Triumph, in large plots in the same field. This allowed a mixing of inoculum and/or races if present. Triadimenol gave only 23% control of net blotch on seed of Zephyr from this source. No opportunity for development of a triadimenol-insensitive strain in our cultivar Zephyr was afforded because untreated seed was grown each year for subsequent trials. Hence the insensitive strain must have come from another cultivar.

None of the new barley cultivars now in use in New Zealand respond to triadimenol for net blotch control, and this fungicide should no longer be used. The Ministry of Agriculture and Fisheries has recently withdrawn recommendations for this fungicide on barley seed. It is highly desirable, therefore, that new cultivars be screened for response before a seed treatment chemical is recommended and that all importations of seed from overseas be treated with an effective fungicide. Imazalil, registered in New Zealand in July 1983, performed well in net blotch control on all cultivars tested.

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