Control of Stripe Rust and Leaf Rust of Wheat with Seed Treatments and Effects of Treatments on the Host

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ABSTRACT

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In greenhouse and field studies at Mount Vernon, Paterson, Pullman, and Walla Walla, WA, triadimefon applied as a slurry to wheat (*Triticum aestivum* L.) seed at 0.5 g a.i./kg (0.6 oz a.i./bu) or higher controlled both stripe rust (*Puccinia striiformis* West.) and leaf rust (*Puccinia recondita* Rob. ex. Desm.) from seedling emergence through the boot stage of plant growth. For winter wheat, control was effective from October to May. Triadimefon at 0.25 g a.i./kg (0.3 oz a.i./bu) controlled the rusts through the tillering stage of plant growth. Fenarimol controlled both rusts at 2 g a.i./kg (2.4 oz a.i./bu) but was phytotoxic and did not control rust at lower rates. Butrizol was effective against leaf rust but not stripe rust. Benomyl at 0.5–2 g a.i./kg (0.6–2.4 oz a.i./bu) and oxycarboxin at 0.5–3.0 g a.i./kg (0.6–3.6 oz a.i./bu) provided only slight control. CGA-64251 reduced the rust but was phytotoxic at 0.12–1 g/kg (0.15–1.2 oz/bu).

Additional key words: chemical control, chemotherapy, fungicides

Chemicals that control cereal rusts when applied to foliage have been known for years. Most of these fungicides are protectants and consequently must be applied several times to ensure disease control at a level adequate to justify use. This expense increases cost of production. Benomyl, oxycarboxin, butrizol, fenarimol, CGA-64251, and triadimefon are systemic fungicides with both protectant and irradicant activities that have recently shown promise as foliar sprays for control of cereal rusts (1,3,12,13).

An alternative and less expensive chemotherapy would be use of a systemic fungicide applied as a seed treatment either alone or in combination with a foliar spray. Such treatments may also be used to complement various types of resistance to rusts. Rowell (12) and Line (*unpublished*) had some success in controlling leaf rust with butrizol seed treatments. Line et al (4,6–8) reported on the evaluation of several seed treatments for control of stripe and leaf rust and their effect on the host, and Frohberger (2) reported on evaluation of triadimefon for control of powdery mildew. Many of the seed treatments provided some control of rusts and powdery mildew but often adversely affected stand and plant growth, especially when used at high rates. Early establishment and development of rusts has become more important in the northwestern United States. Therefore, treatment with systemic fungicides may be an effective tool for control of rust, especially in combination with adult-plant resistance to stripe rust.

Studies were conducted in the greenhouse and field to determine the potential of systemic seed treatments for control of stripe rust and leaf rust of wheat in the northwestern United States and to determine the effects of the treatments on plant growth.

MATERIALS AND METHODS

Wettable powders of the following fungicides were mixed with water and applied as slurries to seed of Nugaines and Lemhi wheat (*Triticum aestivum* L.): oxycarboxin (Plantvax 75%), benomyl (Benlate 50%), fenarimol (EL-222 50%), CGA-64251, butrizol (Indar 50%), and triadimefon (Bayleton 50%). Fungicides were applied at 0.12, 0.25, 0.5, 1, 2, and 3 g a.i./kg (0.15, 0.3, 0.6, 1.2, 2.4, and 3.6 oz/bu) of seed, respectively.

Field-grown wheat plants, either in the field or transplanted to pots in the greenhouse, were inoculated with urediospores of *P. striiformis* and *P. recondita*. In the field, 10 plants from each of four replicates at Pullman, WA, were inoculated with a mixture of urediospores and talc at the seedling, tillering, jointing, boot, and heading stages. Inoculated plants were transplanted to plastic pots, which were placed in controlled environments in the greenhouse for disease development.

Plants transplanted to plastic pots were inoculated in the greenhouse at the seedling, tillering, jointing, boot, and heading stages, and placed in a dew chamber at 13 C for 12 hr. Then they were placed under controlled environments for rust development as follows: Temperatures were programmed for a gradually changing cycle with extremes of 2 and 18 C for stripe rust and 5 and 20 C for leaf rust. Light consisted of daylight supplemented with 4,000 lux from metal-halide lamps to obtain 16-hr photoperiods. Percentage of rust (leaf area covered by rust), infection type based on a scale of 0–9 (9), and any abnormal chlorosis or necrosis were recorded after 15 days.

In field studies, treated and untreated seeds were planted in replicated plots at sites where natural epidemics of one or both rusts occurred. Seeds were planted in 5-, 10-, or 20-ft rows (1 ft apart), depending on the site. Nugaines winter wheat was planted at Pullman, WA, on 14 October and at Mount Vernon, WA, on 25 October. Lemhi spring wheat was planted at Walla Walla, Paterson, Mount Vernon, and Pullman, WA, on 7 April, 7 April, 10 April, and 2 May 1978, respectively. Walla Walla and Paterson plots had high intensities of both stripe rust and leaf rust, whereas Pullman and Mount Vernon had mostly stripe rust. Plots at Paterson were irrigated by center-pivot, overhead sprinklers. Walla Walla and Pullman are in eastern Washington, where rainfall exceeds 50 cm (20 in.) annually and the plots required no supplemental irrigation. At Mount Vernon, in western Washington, winter temperatures are warm and spring and summer temperatures are cool; rainfall exceeds 76 cm (30 in.) annually and stripe rust is nearly always severe on susceptible cultivars. Rust percentages were estimated periodically using the modified Cobb scale (9).

To test the effect of the chemicals on seed germination, seeds treated with fungicides at 2 g a.i./kg (2.4 oz a.i./bu) and untreated seeds were placed on Whatman No. 1 filter paper with all radicles aligned in the same direction, 10 ml of distilled water was added to each dish, and dishes were placed in germinators at 10, 15, 20, 25, 30, and 40 C. The percentage of seeds with emerged radicles was determined after 24 hr. In other tests, seeds were planted in paper pots containing 130 g of a homogeneous

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mixture of peat moss, perlite, sand, soil, and vermiculite (3:1:1:1:2) fertilized with 215 g of Osmocote (a slow-release fertilizer consisting of 14% nitrogen, 14% phosphoric acid, and 14% soluble potash) per 30 L of potting mixture. Watering was controlled to prevent leaching of seed treatments. Emergence was determined, plants were removed from the pots, and leaves and roots were measured 15 days after planting. In the field at Pullman and Mount Vernon, shoots and roots were measured and percent emergence was determined 30 days after planting.

RESULTS AND DISCUSSION

Control of stripe rust. Results from field and greenhouse inoculations with stripe rust were similar (Fig. 1). In all tests, the untreated checks had 70–80% stripe rust. Benomyl at 2 g/kg (2.4 oz/bu), oxycarboxin at 2 g/kg (2.4 oz/bu) or higher, and fenarimol at 0.5 g/kg (0.6 oz/bu) or higher resulted in significantly less stripe rust up to the jointing stage but not at later stages (Fig. 1). Lower rates of fungicide did not reduce stripe rust intensity.

Triadimefon provided the best control and appeared to be slightly more effective on plants inoculated in the field; 0.12 g/kg (0.15 oz/bu) controlled stripe rust up to the boot stage with field inoculations but only to the jointing stage with greenhouse inoculations (Fig. 1). This fungicide at 0.25 g/kg (0.3 oz/bu) or higher controlled rust up to the heading stage when inoculated either in the field or greenhouse. Stripe rust intensity at the heading stage on plants from seed treated with triadimefon at 1 g/kg (1.2 oz/bu) or higher was less than 10% compared with 80% intensity on the checks. Triadimefon at higher rates also prevented sporulation of the pathogen. Infection types were 8, 8, 5, 2, and 0 with triadimefon at 0.12, 0.25, 0.5, 1, and 2 g/kg (0.25, 0.3, 0.6, 1.2, and 2.4 oz/bu), respectively, but 8–9 (scale of 0–9) with all other treatments and the checks.

Treatment-disease interactions were significant using regression analysis of the combined field and greenhouse data; their regressions are presented in Table 1. Fenarimol and oxycarboxin showed a significant linear relationship between fungicide rates and the percent rust control from seedling to jointing stages but not beyond the jointing stage. However, percent rust control with triadimefon was linearly related to fungicide rates from the jointing to heading stages but not at the seedling and tillering stages because all rates tested provided nearly complete control up to the jointing stage. At the later stage, the higher rates were more effective. Using the regression equation, when rust was 70–80% on the untreated checks, 0.12, 0.25, 0.5, and 1 g/kg of triadimefon reduced stripe rust to 31, 29, 24, and 13% at the boot stage and 46, 43, 36, and 22% at the heading stage, respectively.

Even though oxycarboxin, benomyl, fenarimol, or butrizol controlled rust in greenhouse tests, they did not control naturally occurring stripe rust at the boot or heading stages at four field locations characterized by different moistures, temperature regimes, and management

Table 1. Linear regression analysis of the effects of seed treatments on stripe rust and leaf rust intensity on plants grown in the field and transplanted to the greenhouse

Seed treatment	Regression equation ($Y = a - bx$)[a] Seedling stage	Tillering stage	Jointing stage	Boot stage	Heading stage
			Stripe rust		
Oxycarboxin	$Y = 66-16x$	$Y = 79-28x$	$Y = 78-19x$	···	···
Fenarimol	$Y = 44-21x$	$Y = 79-35x$	$Y = 76-33x$	···	···
Triadimefon	···	···	$Y = 11-7x$	$Y = 34-21x$	$Y = 50-28x$
			Leaf rust		
Oxycarboxin	$Y = 18-9x$	$Y = 73-7x$	···	···	···
Fenarimol	$Y = 49-26x$	$Y = 65-35x$	$Y = 53-16x$	···	···
Butrizol	$Y = 16-9x$	$Y = 22-13x$	$Y = 11-7x$	$Y = 18-11x$	$Y = 27-13x$
Triadimefon	···	$Y = 17-11x$	$Y = 22-12x$	$Y = 29-18x$	$Y = 39-15x$

[a] Y = Predicted percent rust infection, x = fungicide rate (g/kg), a = intercept with Y axis, and b = the slope. Regression equations presented were highly significant (probability greater than $F = 0.0001$). Those not presented were not significant (probability greater than $F = <0.05$).

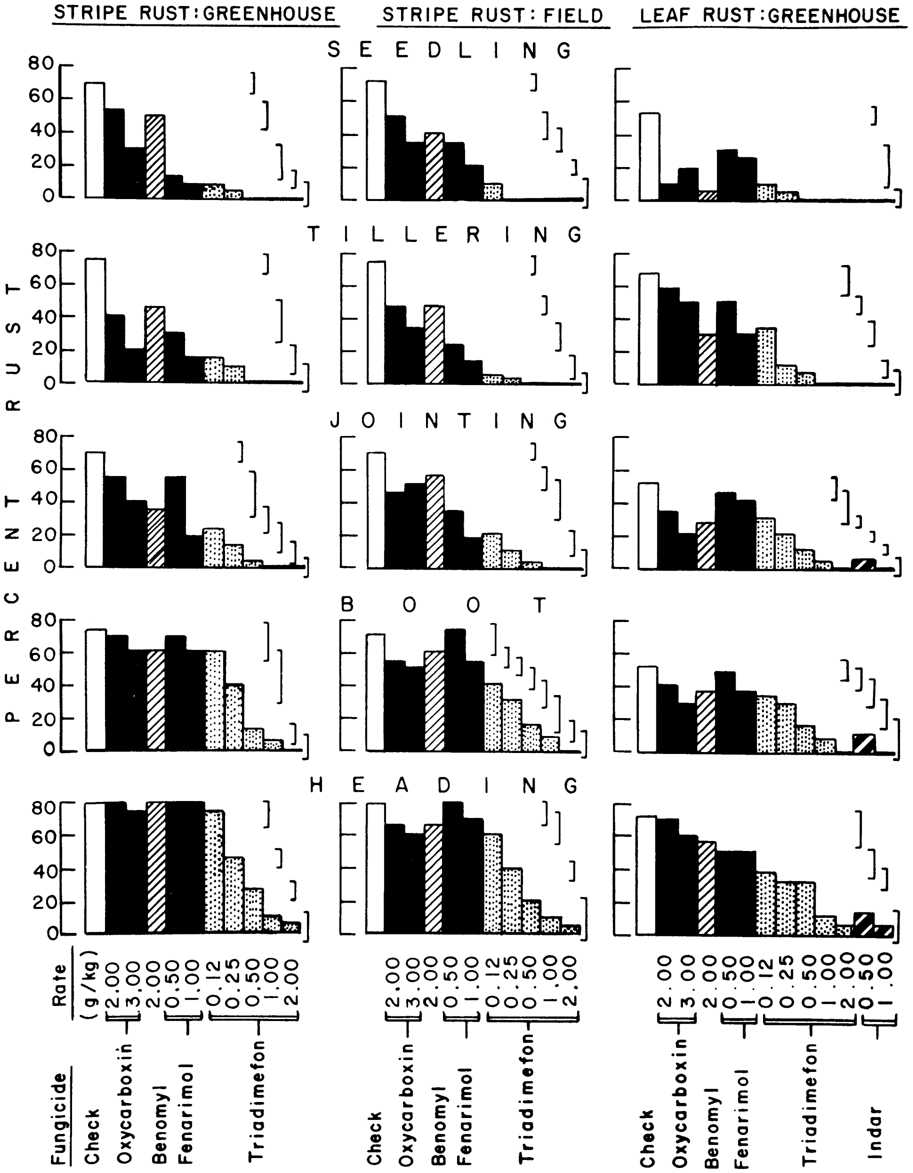

Fig. 1. Effects of seed treatments on stripe rust intensity when Nugaines wheat at five stages of growth was inoculated with stripe rust in field plots or under controlled environmental conditions in the greenhouse and with leaf rust in the greenhouse. Each inoculation was replicated four times. Rust intensities designated by the same horizontal bracket are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

practices.

CGA-64251 controlled stripe rust up to the boot stage at Paterson and Pullman and significantly reduced rust at Walla Walla when applied at 1 g/kg (1.2 oz/bu) but did not suppress rust at Mount Vernon (Fig. 2). At Paterson, Walla Walla, and Pullman, neither linear nor quadratic contrasts were significant at the boot stage but the linear contrast was significant at the heading stage (Table 1).

Stripe rust was reduced 30, 38, and 95% at the boot stage and 25, 60, and 90% at the heading stage when Lemhi was treated at 0.5, 1, and 2 g/kg (0.6, 1.2, and 2.4 oz/bu), respectively. Results with Nugaines at Mount Vernon were even more spectacular; at 0.5 g/kg (0.6 oz/bu) or higher, control was still effective at the heading stage in late May, 6 mo after the seed was planted (Fig. 2). At the boot stage, the linear contrasts (Table 2) with triadimefon were significant only at Walla Walla and Mount Vernon, primarily because all rates controlled stripe rust at the other sites. Linear contrasts were significant at all the locations at the heading stage.

Table 2. Linear regression analysis of the effects of seed treatments on stripe rust and leaf rust intensity at field sites in Washington State

Cultivar	Location	Seed treatment	Regression equation ($Y = a - bx$)[a] Boot stage	Heading stage
		Stripe rust		
Nugaines	Mt. Vernon	Triadimefon	$Y = 43 - 25x$	$Y = 80 - 8x$
Lemhi	Mt. Vernon	Triadimefon	$Y = 43 - 21x$	$Y = 80 - 35x$
	Walla Walla	Triadimefon	$Y = 19 - 9x$	$Y = 89 - 42x$
	Pullman	Triadimefon	···	$Y = 86 - 41x$
	Paterson	Triadimefon	···	$Y = 67 - 35x$
	Paterson	CGA-64251	···	$Y = 94 - 30x$
		Leaf rust		
Lemhi	Paterson	Triadimefon	···	$Y = 31 - 8x$
	Paterson	Butrizol	···	$Y = 28 - 10x$

[a] Y = Predicted percent rust infection, x = fungicide rate (g/kg), and a = intercept with Y axis, and b = the slope. Regression equations presented were highly significant (probability greater than F = 0.0001). Those not presented were not significant (probability greater than $F = <0.05$).

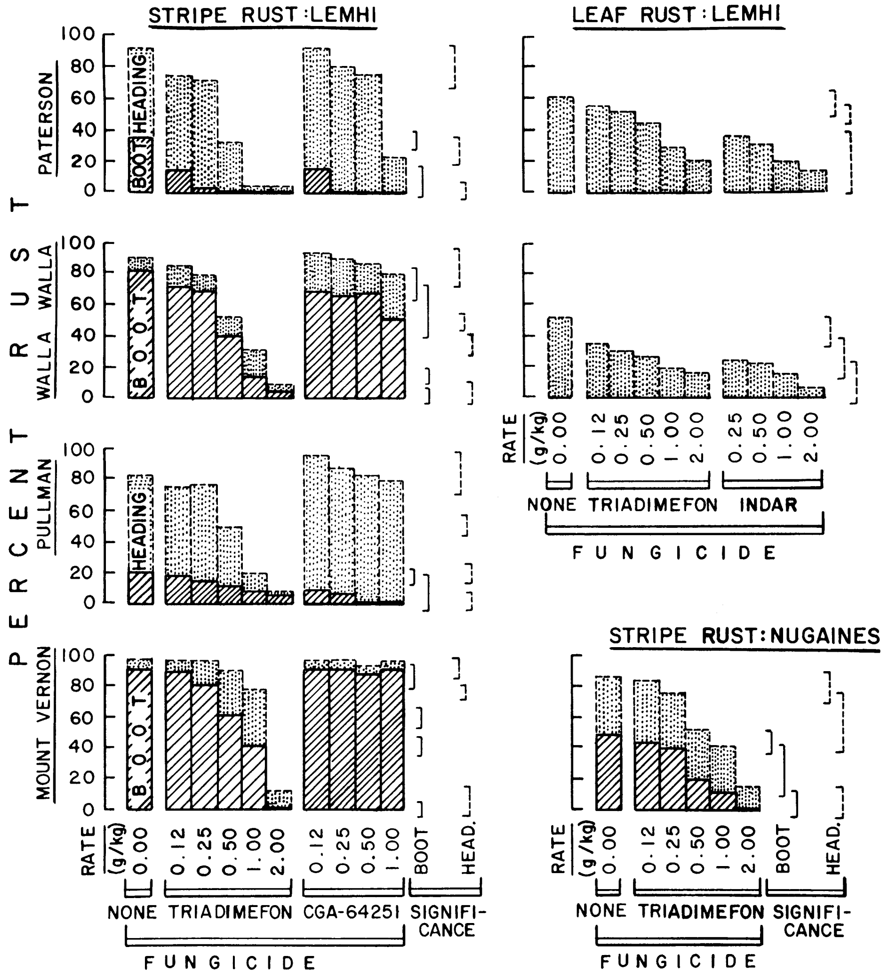

Fig. 2. Effect of seed treatments on stripe rust intensities on Lemhi wheat at Paterson, Walla Walla, Pullman, and Mount Vernon, WA, and Nugaines at Mount Vernon at boot and heading stages of plant growth and on leaf rust intensity on Lemhi at the heading stage at Paterson, WA. Each plot was replicated four times. Rust intensities designated by the same bracket are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Seed treatments with benomyl controlled stripe rust on Nugaines in the greenhouse but not on Lemhi in the field. Nugaines has high-temperature, adult-plant resistance, and although not expressed at the temperatures in this study, there may have been some complementary interaction. Foliar applications of benomyl have not controlled stripe rust in previous studies (3). Oxycarboxin was effective only in the two areas with the highest rainfall (Mount Vernon and Pullman) or under irrigation (Paterson). Stripe rust was controlled at Pullman with 3 g/kg (3.6 oz/bu), at Mt. Vernon with 2 g/kg (2.4 oz/bu) or more, and at Paterson with 1 g/kg (1.2 oz/bu) or more. In previous work (3,5,8) foliar applications of oxycarboxin were most effective against stripe rust at sites where rains occurred before and after application.

CGA-64251 was effective against stripe rust until the boot stage at Paterson and Pullman but did not provide control at any stage of growth at Walla Walla and Mount Vernon (Fig. 2). Fenarimol at 1 g/kg (1.2 oz/bu) controlled stripe rust in the greenhouse but not in the field. As a foliar spray, fenarimol was effective for only a few weeks (3,5,8), hence the short period of effectiveness as a seed treatment in the field is not surprising.

Control of leaf rust. Benomyl and oxycarboxin at 2 g/kg (2.4 oz/bu) and fenarimol at 0.5 and 1 g/kg (0.6 and 1.2 oz/bu) controlled leaf rust up to the tillering stage in the greenhouse. Oxycarboxin at 3 g/kg (3.6 oz/bu) was effective up to the boot stage.

Linear contrasts were significant from the seedling to the jointing stages for fenarimol and from the seedling to the tillering stages for oxycarboxin (Table 1). Fenarimol regression lines were steeper than oxycarboxin lines.

Best control of leaf rust in the field was obtained with butrizol and triadimefon. Butrizol was usually more effective than triadimefon when used at the same rate. Linear contrasts of butrizol were significant from the seedling to the heading stages (Table 1) and its predicted lines had a lower intercept than those of the triadimefon, except in the field at Paterson at the heading stage (Table 2), where their predicted lines showed similar intercepts and slopes. Butrizol at 0.5 g/kg (0.6 oz/bu) provided 100% control up to the boot stage and 40% control up to the heading stage, and at 1 g/kg (1.2 oz/bu), it provided nearly complete control until the wheat was headed (Fig. 2). It controlled leaf rust at most rates tested in the greenhouse and the field (Figs. 1 and 2).

Triadimefon at 0.12 g/kg (0.15 oz/bu) did not control leaf rust beyond the boot stage, but when seed was treated at 0.25, 0.5, and 1 g/kg (0.3, 0.6, and 1.2 oz/bu), leaf rust was reduced at the heading stage by 50, 50, and 80%, respectively, compared with the untreated check (Fig. 2). Triadimefon at 2 g/kg (2.4 oz/bu) provided nearly complete control up to the heading stage. Lower rates (0.12–0.25 g/kg or 0.15–0.3 oz/bu) of triadimefon were not effective, but at 0.5 g/kg (0.6 oz/bu) or higher, they provided good control of the rust. This finding agrees with Line's results with experimental sprays in 1975 (5). Hence, when leaf rust infection was not very severe, triadimefon and butrizol were equally effective in controlling the disease. However, under ideal conditions for infection (greenhouse inoculations), butrizol was more effective than triadimefon.

Oxycarboxin, benomyl, and CGA-64251 did not control leaf rust in the heading stage in the field at Paterson and Walla Walla. In 1976, Rowell (10–12) showed that oxycarboxin was promising for controlling leaf rust by seed treatment, but large quantities of chemical (16 g/kg) were required for long-lasting effectiveness. Such rates are too high for practical use and would be difficult to apply to the seed.

Effects of seed treatments on plants. Untreated seeds showed maximum germination of 95–100% on moist filter paper at temperatures between 15 and 30 C (Fig. 3). Benomyl and oxycarboxin had no effect on germination, but butrizol at 35 C, triadimefon at 10, 15, and 35 C, and fenarimol and CGA-64251 at all temperatures resulted in less germination (Fig. 3). The effect of seed treatments on emergence and shoot and root length of Lemhi and Nugaines in the greenhouse and field is presented in Tables 3–5. Seed treatment with benomyl and oxycarboxin did not significantly reduce the stand of Nugaines and Lemhi at any of the rates tested or at any field location. Triadimefon at 0.5 g/kg (0.6 oz/bu) or higher significantly reduced the plant stand of Lemhi at Pullman but did not affect the stand of either Nugaines or Lemhi at other locations or in the greenhouse at rates lower than 0.5 g/kg (0.6 oz/bu). Stand reduction was linearly related to the rates of triadimefon; the higher the

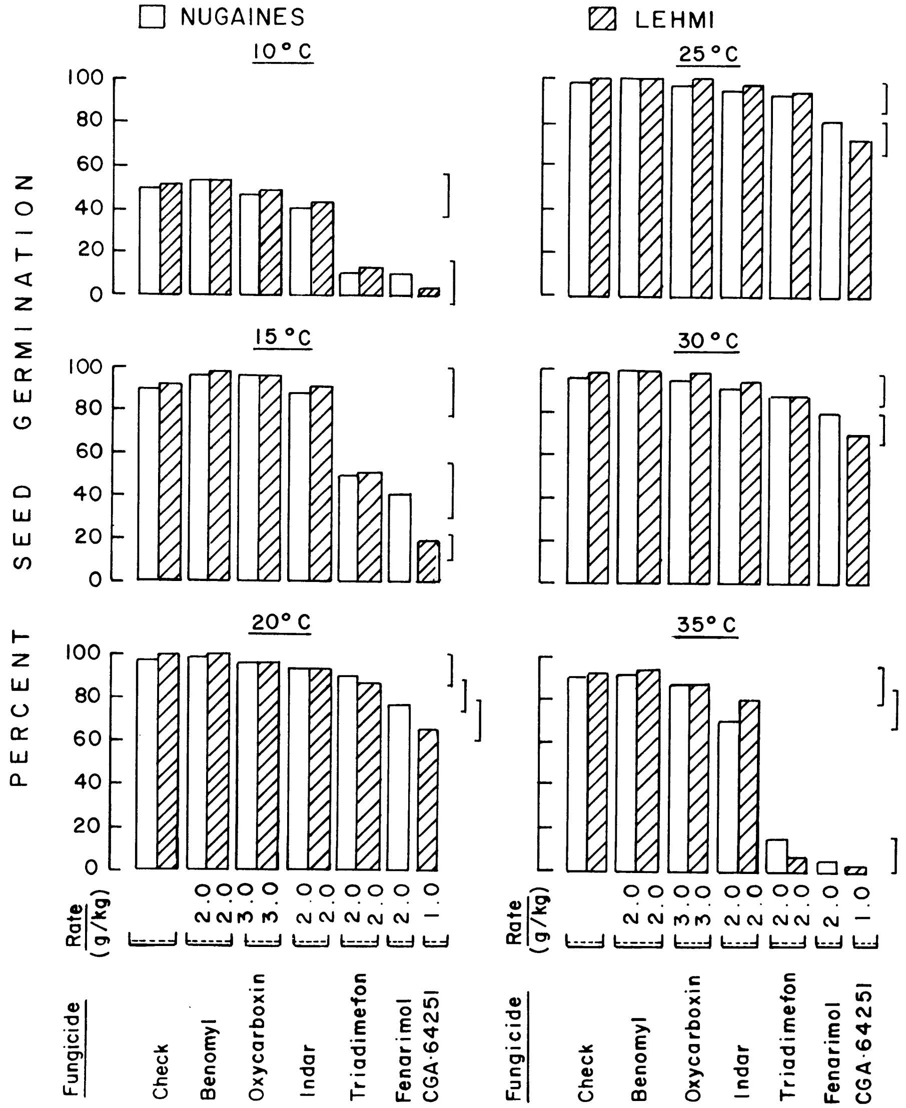

Fig. 3. Percent germination of Nugaines winter wheat and Lemhi spring wheat treated with systemic fungicides, after 24 hr at different temperatures. Four replicates were provided for each temperature.

Table 3. Effects of seed treatments on emergence and shoot and root length of Nugaines winter wheat after 15 days in the greenhouse and 30 days at the field sites

Fungicide	Rate (g a.i./kg)	Emergence (%)			Shoot length (cm)		Root length (cm)	
		Greenhouse	Mt. Vernon	Pullman	Greenhouse	Pullman	Greenhouse	Pullman
None (check)		80 ab[a]	63 a	51 a	12 abc	8 abc	12 abc	24 ab
Triadimefon	0.12	98 a	62 a	41 a	11 abcd	7 bcd	15 a	25 a
	0.25	88 ab	53 ab	48 a	10 cde	7 cde	11 bcd	20 bcdef
	0.5	78 ab	43 ab	45 a	9 def	7 cde	9 def	18 defg
	1.0	83 ab	31 ab	40 b	9 def	5 def	9 def	17 defg
	2.0	70 b	31 ab	37 b	7 gh	4 ef	7 gh	16 efg
Butrizol	0.25	95 a	55 ab	46 a	10 cde	4 ef	12 abc	22 abcd
	0.5	85 ab	56 ab	43 ab	10 cde	4 ef	11 bcd	21 abcd
	1.0	85 ab	49 ab	20 c	10 cde	4 ef	11 bcd	16 efgh
	2.0	78 ab	48 ab	5 c	10 cde	4 ef	10 cde	15 gh
Fenarimol	0.25	85 ab	47 ab	49 a	9 def	5 def	10 cde	16 efgh
	0.5	75 ab	32 ab	43 b	9 def	4 ef	10 cde	17 defg
	1.0	78 ab	28 b	34 b	9 def	4 ef	9 def	16 gh
	2.0	65 c	21 b	16 c	6 h	3 f	6 h	13 h

[a] Means are the result of four replicates for each location; those in the same column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 4. Effects of seed treatments on emergence and shoot and root length of Lemhi spring wheat after 15 days in the greenhouse and 30 days at the field sites

		Emergence (%)					Shoot length (cm)		Root length (cm)	
Fungicide	Rate (g a.i./kg)	Greenhouse	Paterson	Pullman	Walla Walla	Mt. Vernon	Greenhouse	Mt. Vernon	Greenhouse	Mt. Vernon
None (check)		90 a[a]	83 ab	83 a	86 ab	87 a	13 a	12 a	17 bc	13 a
Triadimefon	0.12	98 a	93 a	79 a	91 a	92 a	11 abc	11 ab	15 cd	12 ab
	0.25	93 a	93 a	79 a	85 ab	90 a	11 abc	11 ab	15 cd	10 abcde
	0.5	88 a	90 ab	63 b	83 ab	90 a	10 bc	10 bc	13 de	9 abcde
	1.0	90 a	90 ab	60 b	48 bc	80 ab	10 bc	9 bcd	13 de	10 abcde
	2.0	88 a	83 ab	41 c	71 abc	89 a	8 c	6 ef	10 fgh	7 ef
Butrizol	0.25	90 a	79 abc	84 a	83 ab	93 a	11 abc	10 abc	18 ab	9 abcde
	0.5	88 a	84 ab	78 a	82 ab	91 a	11 abc	8 cd	18 ab	10 abcde
	1.0	80 ab	80 abc	41 c	85 ab	90 a	12 ab	6 ef	19 ab	8 cdef
	2.0	80 ab	75 c	6 d	83 ab	87 a	11 abc	4 g	15 cd	7 ef
CGA-64251	0.12	60 bc	77 bc	52 b	80 ab	69 b	12 ab	11 abc	17 bc	10 abcde
	0.25	58 c	73 c	34 c	75 ab	60 bc	9 bc	9 bcd	12 def	9 bcde
	0.5	35 d	68 cd	21 cd	64 bc	56 c	8 c	8 de	9 fgh	8 cdef
	1.0	25 d	60 d	13 d	51 c	53 c	6 d	5 fg	8 h	5 f

[a] Means are the result of four replicates; those in the same column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 5. Linear regression analysis of the effects of seed treatments on emergence, shoot length, and root growth of Nugaines winter wheat and Lemhi spring wheat in greenhouse and field tests in Washington State

			Regression equation ($Y = a-bx$)[a]		
Cultivar	Location	Seed treatment	Emergence	Shoot length	Root length
Nugaines	Greenhouse	Fenarimol	$Y = 99-22x$	$Y = 10-2x$	$Y = 8-3x$
	Greenhouse	Triadimefon	···	$Y = 10-2x$	$Y = 11-2x$
	Pullman	Fenarimol	$Y = 53-17x$	···	$Y = 18-2x$
	Pullman	Butrizol	$Y = 52-29x$	···	$Y = 23-4x$
	Pullman	Triadimefon	$Y = 49-7x$	$Y = 11-3x$	$Y = 11-3x$
Lemhi	Greenhouse	CGA-64251	$Y = 99-23x$	$Y = 11-3x$	$Y = 11-3x$
	Greenhouse	Butrizol	···	···	$Y = 11-3x$
	Mt. Vernon	CGA-64251	$Y = 66-8x$	$Y = 11-3x$	$Y = 11-2x$
	Mt. Vernon	Butrizol	···	$Y = 10-3x$	$Y = 12-3x$
	Mt. Vernon	Triadimefon	···	$Y = 11-2x$	$Y = 11-2x$
	Pullman	CGA-64251	$Y = 48-20x$	···	···
	Pullman	Butrizol	$Y = 95-46x$	···	···
	Pullman	Triadimefon	$Y = 78-21x$	···	···
	Paterson	CGA-64251	$Y = 78-9x$	···	···

[a] Y = Predicted percent emergence, shoot length, or root length, x = fungicide rate (g/kg). All these equations were significant (probability greater than $F = 0.05$ to 0.0001).

rates, the lower the stand (Table 5). Frohberger (2) observed that stand and growth may also have been affected after seed treatment with triadimefon if 1) seed was of low germinability; 2) soil was too wet or too dry, compacted, or crusted; or 3) soil temperatures were low enough to retard emergence. Butrizol resulted in significantly less stand of Nugaines and Lemhi at Pullman with 0.5 g/kg (0.6 oz/bu) or higher, and of Lemhi at Paterson at 2.0 g/kg (2.4 oz/bu).

Plots at Pullman were the driest during seedling emergence and the soils had the finest texture (silt loam mixed with clay loam). Rowell (11) observed severe stand loss when seeds treated with butrizol at a high rate were planted in dry soil. Fenarimol, which was tested only on Nugaines, resulted in loss of emergence at all rates tested at Pullman and only at the highest rate in the greenhouse and at Mt. Vernon (Tables 3 and 5). CGA-64251, evaluated only on Lemhi, affected stand at all rates (0.12–1 g/kg or 0.15–1.2 oz/bu) tested in the greenhouse and at Mount Vernon, at rates higher than 0.25 g/kg (0.3 oz/bu) at Paterson and Pullman, and only at the highest rate (1 g/kg or 1.2 oz/bu) at Walla Walla (Tables 4 and 5). These results indicate that fenarimol and CGA-64251 seed treatments are likely to be more harmful to plant stand than the other treatments.

Shoot and root growth of Lemhi and Nugaines wheat seedlings, as measured at 15 days in the greenhouse and 30 days in the field, was retarded by one or more rates of all fungicide seed treatments except benomyl and oxycarboxin (Tables 3–5). Butrizol at rates higher than 0.5 g/kg (0.6 oz/bu) resulted in significantly less shoot growth of Lemhi at Mount Vernon and less shoot and root growth of Nugaines at Pullman at all rates, but it did not reduce shoot growth of Lemhi and Nugaines in the greenhouse. This chemical at rates higher than 1 g/kg (1.2 oz/bu) resulted in significantly less root growth for Lemhi and Nugaines than the check in the field. There was no effect on roots observed at any of the rates tested in the greenhouse. Triadimefon resulted in significantly less shoot and root growth at 2 g/kg (2.4 oz/bu) but did not affect growth at 0.25 g/kg (0.3 oz/bu) or less. Fenarimol at all rates (0.25–2 g/kg or 0.3–2.4 oz/bu) tested retarded shoot and root growth both in the greenhouse and in the field. CGA-64251 at rates higher than 0.25 g/kg (0.3 oz/bu) resulted in significantly less root growth in both the greenhouse and field.

Triadimefon provided the best control of both rusts. Control was obtained in both fall- and spring-planted wheat as well as in the greenhouse. It controlled rusts even at the highest intensities and at rates as low as 0.5 g/kg (0.6 oz/bu). However, at 2 g/kg (2.4 oz/bu), triadimefon retarded growth. Further studies are needed to determine how long such growth retardation would last and if there are some fast-growing cultivars that would escape this side-effect. The other fungicides, when used as seed treatments, were too phytotoxic, did not control the rust, or both. Butrizol was effective against leaf rust but not stripe rust and was phytotoxic at high rates. Benomyl and oxycarboxin did not retard growth of wheat seedlings but provided inadequate control of either stripe or leaf rust. Fenarimol was highly phytotoxic and provided inadequate control of rust. CGA-64251 reduced rust at some sites but those rates were phytotoxic.

The most effective control strategy for stripe and leaf rust may be use of triadimefon as a seed treatment at 0.5 g a.i./kg (0.6 oz a.i./bu) in combination with adult plant resistance to stripe rust, or in combination with foliar sprays. This strategy will involve the most effective use of pesticides at the lowest rates and will minimize phytotoxicity of triadimefon. A low rate of seed treatment would control early rust development. Adult-plant resistance and/or foliar sprays would control late rust development. This would cost less than applying an early spray.

Triadimefon at 0.5 g/kg (0.6 oz/bu) on Nugaines significantly controlled stripe rust up to the boot stage and was highly effective during the earlier stages. Nugaines is very susceptible to stripe rust in the seedling stage but has moderate adult-plant, high-temperature resistance to the rust. Therefore, a late foliar application of the chemical for control of stripe rust may not be necessary. For cultivars that do not have adult-plant resistance to stripe rust (such as Lemhi) or in years when leaf rust, which develops late in the growing season, is severe, a foliar application of triadimefon at the later growth stages may be necessary. Rusts can be severe early in the season in the Pacific Northwest. In the drier areas of the region, yield potential is too low for economical benefits from foliar sprays. Seed treatment may provide protection from these diseases during that period at a cost that could be recovered by increasing yield.

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