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# FUNGICIDE SEED TREATMENT EFFECTS ON EMERGENCE OF DEEPLY PLANTED WINTER WHEAT

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## INTRODUCTION

Winter wheat in low-rainfall regions of the Pacific Northwest (PNW) is generally planted into a stubble-mulch fallow consisting of moist soil below a deep mulch of dry soil plus crop residue. Moisture required for seedling emergence often occurs at depths greater than 4- to 6-in. below the surface. Deep-furrow drills move and pack dry soil above and to the side of the seed row so that coleoptiles emerge from effective seed depths of 2- to 5-in. Hazards associated with deep seed placement include seed rotting if seed-zone moisture is insufficient for germination and coleoptile growth, pre-emergence wind erosion that increases effective planting depth by filling drill rows, and rainfall that crusts the soil surface before seedling emergence. Lindstrom et al. (1976) concluded that germination is seldom a limiting factor in stubble-mulch fallow and that the rate of coleoptile elongation before emergence is the most important determinant of stand establishment. Factors that reduce the rate and magnitude of coleoptile elongation increase the risk for stand failure.

Most (95 percent) winter wheat seed planted in the PNW is treated with a fungicide to control smut diseases. Vitavax was the dominant treatment during the past 25 years. In some instances Vitavax delays germination and emergence (Gusta et al., 1994), although this effect is not known to be widespread. Thiram, FloPro IMZ, NuZone, and/or Apron are applied with Vitavax to broaden the spectrum of diseases controlled. FloPro IMZ and NuZone are systemically translocated fungicides (the active ingredient for both is imazalil) that can reduce emergence, stand establishment, and crown depth by reducing the length of wheat subcrown internodes (Chinn et al., 1980).

Baytan, Dividend, and Raxil are systemically translocated triazole fungicides that efficiently control smuts and several other diseases of cereals. Triazole fungicides affect many plant growth properties (Scheinpflug and Duben, 1988). Very low rates of seed treatment may stimulate shoot growth and increase tolerance to drought, heat, chilling, ozone, and sulfur dioxide (Fletcher and Nath, 1984; Gao et al., 1988). Higher application rates are phytotoxic. Potential growth regulatory effects for Baytan include delayed or reduced emergence, disturbed geotropism, and reductions in growth of coleoptiles, roots and shoots, and in tillering and freezing tolerance (Buchenauer and Rohner, 1981; Förster et al., 1980; Gusta et al., 1994; Montfort et al., 1996; Scheinpflug and Duben, 1988). Some of these effects have also been described for Raxil (Hack, 1994; Holderness, 1990; Kaspers et al., 1987).

In our experience (Smiley and Patterson, 1995) deeply planted winter wheat often appears to emerge more quickly when treated with Dividend than RTU Vitavax Thiram. Effects of seed treatments on winter wheat emergence have not been described for PNW stubble-mulch fallow systems. Objectives of this study were to determine effects of Dividend, FloPro IMZ, NuZone, and Raxil on seedling emergence relative to seed treated with RTU Vitavax Thiram, or untreated seed.

## METHODS

Seed treatment fungicides were compared

in three greenhouse and seven field experiments from 1993 to 1995. Gaucho insecticide was included in field experiments during 1995. Winter wheat seed was planted into fields managed as winter wheat-summer fallow rotations; locations and conditions are listed in Table 1.

Emergence was evaluated in greenhouse experiments that simulated plantings at 5-in. depth into stubble-mulch fallow. The experimental design was a 3 x 4 factorial with six replicates; three levels of seed-zone moisture (7, 10, or 15 percent by weight) and four fungicide seed treatments (untreated, Dividend, RTU Vitavax Thiram, or NuZone). Batches of Walla Walla silt loam were wetted to specified water contents and placed into 3x6-in. plastic cylinders with solid bottoms. Dry soil weighed 1.5 lb/cylinder. Five seeds per cylinder were planted at 1-in. depth. A 4-in. layer of dry soil was placed into a second cylinder positioned and sealed above the cylinder containing wheat seed in moist soil. Soil columns were incubated in the greenhouse at 70-75 $^{o}$F and emerged seedlings were counted daily. The study was performed three times and data were averaged before analysis.

Additional greenhouse experiments were performed to examine emergence of seed treated with Raxil Thiram. One study was performed as described above, by substituting Raxil Thiram for NuZone. Apron was applied as a co-fungicide with Dividend in accordance with requirements of revised commercial packaging of Dividend for the PNW. A repeated sequence included only two fungicide treatments (Raxil Thiram and Dividend + Apron), plus a planting depth variable (2 or 4 inches of dry soil overlying the moist soil), and a "surface crusting" variable (with or without crusting). Surface crusting was simulated by saturating the surface 0.75-in. of dry soil with water and promoting rapid drying by blowing air across the surface.

Field tests included up to five winter wheat varieties planted at the rate of 18 seeds/sq ft at 2- to 5-in. depth either with a Hege plot drill (5 rows at 12-in. spacing in 1993; 4 rows at 14-in. spacing in 1994) or a John Deere HZ drill (4 rows at 14-in. spacing in 1995). Planting depth was in accordance with commercial practices, 1 in. into moist soil below a dust mulch. Experiments were randomized complete block designs with five or six replications per treatment. Plots measured 5 x 20 ft in 1993 and 1994, and 5 x 40 ft in 1995.

Seedling emergence was monitored at 2- to 7-day intervals depending on the depth of planting and rate of seedling emergence. A qualitative emergence scale was used in view of the large number of plots, distance between plots, and frequency of observation. Ratings during 1993 and 1994 were as follows: 0 = <10 percent seedlings emerged, 1 = 10-50 percent, 2 = 50-85 percent, and 3 = >85 percent. Ratings during 1995 were as follows: 0 = no seedlings emerged, 1 = <15 percent seedlings emerged, 2 = 15-40 percent, 3 = 40-60 percent, 4 = 60-85 percent, and 5 = >85 percent. Stand counts in three 1-ft row sections of each replicate were made for selected treatments and experiments. If emergence did not differ among varieties, data for each fungicide treatment was summed across varieties before analysis of variance.

During 1995 an experiment evaluated emergence as affected by depth of planting at a single location. Summer rainfall was plentiful and the depth of dry soil mulch was only 1 in. Sweep rod-weeding was used to create dry mulches at two additional depths to establish planting depths of 1, 3, and 5 in.

Table 1. Characteristics of seven locations where seedling emergence was evaluated.

| Location | Soil series and texture† | Annual precipitation (inch) | Planting date | Planting depth (inch) | Seed zone | |
|---|---|---|---|---|---|---|
| | | | | | Temperature (°F) | Moisture (percent wt/wt) |
| Arlington | Walla Walla | 11 | 9 Sept 1993 | 4 | 74 | 7.7 |
| Arlington | Walla Walla | 11 | 25 Aug 1995 | 4.5 | 71 | 10.1 |
| Benton City | Ritzville | 11 | 10 Sept 1993 | 5 | 74 | 9.1 |
| Benton City | Ritzville | 11 | 2 Sept 1994 | 5 | 78 | 6.6 |
| Echo | Adkins | 10 | 28 Aug 1995 | 3.5 | 80 | 10.1 |
| Helix | Walla Walla | 15 | 13 Sept 1993 | 3.5 | 78 | 11.7 |
| Ione | Ritzville | 11 | 7 Sept 1994 | 4.5 | 78 | 4.9 |
| Moro | Walla Walla | 12 | 9 Sept 1993 | 2 | 75 | 10.1 |
| Pendleton | Walla Walla | 16 | 13 Sept 1993 | 3 | 75 | 17.0 |
| Pendleton | Walla Walla | 16 | 8 Sept 1995 | 1 | 77 | 15.9 |
| Pendleton | Walla Walla | 16 | 8 Sept 1995 | 3 | 73 | 14.9 |
| Pendleton | Walla Walla | 16 | 8 Sept 1995 | 5 | 71 | 12.6 |

† All soils were silt loams except for the Adkins fine sandy loam near Echo.

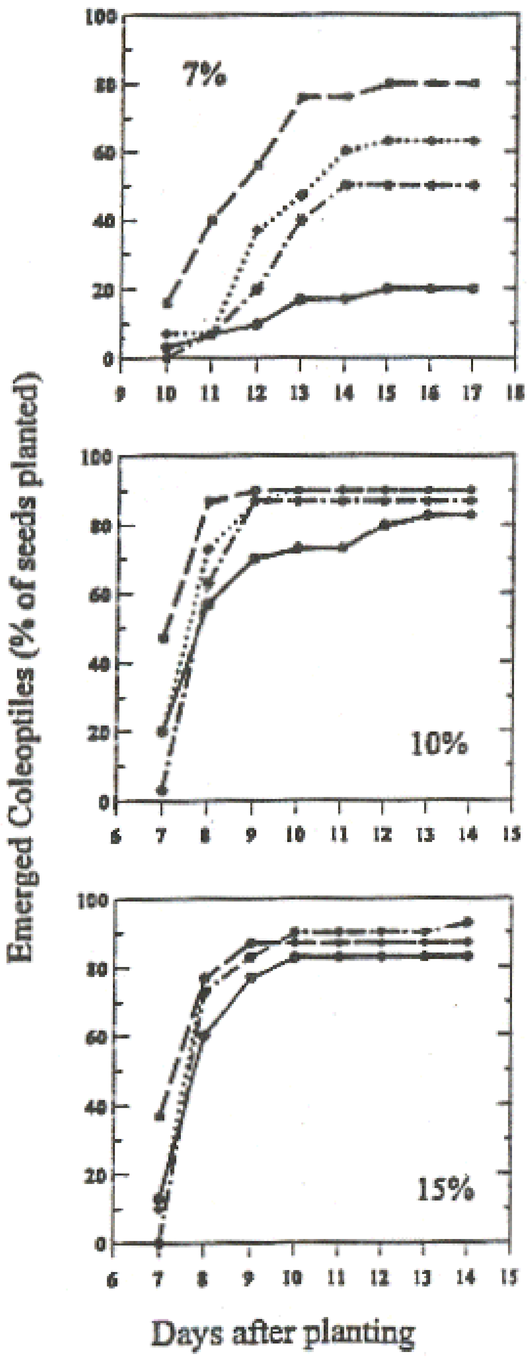
Wheat was planted as planned even though rain moistened the entire profile of each depth treatment before plots were planted. The experiment was a split-plot design; main plots were three planting depths replicated four times, and subplots were five seed treatments. Two 2-ft. intervals were randomly marked in each plot. Emerged seedlings were counted at 2-day intervals and data from the marked areas of each plot were summed before analysis.

## RESULTS

Emergence through five inches of warm soil in the greenhouse was most successful when seed was treated with fungicides and seed-zone soil moisture contents were 10 percent or higher (Table 2). Main effects of soil moisture and fungicide were significant. Compared with untreated seed, Dividend and NuZone improved emergence at 7 percent moisture. Dividend and RTU Vitavax Thiram improved emergence at 15 percent moisture and also tended to do so at 10 percent.

Raxil Thiram was substituted for NuZone in a follow-up study. Seed treated with Dividend + Apron emerged from 5-in. depth one or two days more quickly than untreated seed or seed treated with RTU Vitavax Thiram or Raxil Thiram at each soil moisture (Fig. 1). This relationship was most apparent in the driest soil, where emergence was slower

Fig. 1. Emergence of Stephens wheat at daily intervals after planting at 5-inch depth (1-inch into moist soil covered by 4-inch dry soil) into warm (75 °F) silt loam at three moisture contents (7, 10 or 15 percent) in the greenhouse; ● = untreated, ■ = Dividend + Apron, ◆ = RTU Vitavax Thiram, and ★ = Raxil Thiram.




and less complete for all treatments. Emergence of seed treated with Dividend + Apron was significantly higher than for all other treatments up to 13 days after planting into soil at 7 percent water content. All fungicides provided superior emergence over untreated seed and this was significant at 7 percent soil moisture, 14 days after planting and later.

Soil moisture and fungicides did not affect percentages of seed that germinated (>97 percent in all treatments). At 7 percent water content, percentages of coleoptiles that did not emerge by 21 days after planting were higher for untreated seed (53 percent) than seed treated with Raxil Thiram (27 percent), RTU Vitavax Thiram (20 percent) or Dividend + Apron (17 percent).

Emergence through crusted soil was uniformly poor in the third greenhouse experiment. Final emergence was 0, 9, and 13 percent at seed-zone moisture contents of 7, 10 and 15 percent, and was unaffected by fungicides or planting depth. Emergence in uncrusted soil improved as soil moisture increased and planting depth decreased (Table 3). Emergence at 10 percent moisture was more complete with Dividend + Apron than Raxil Thiram 12 days after planting. Emergence 14 days after planting was significantly influenced by planting depth (78 vs 68 percent at 3- and 5-in.) and soil water content (46, 81 and 93 percent at 7, 10 and 15 percent water) but not fungicide (76 and 70 percent for Dividend + Apron and Raxil Thiram). Seed germination was 99 percent, but 23 percent of the coleoptiles did not emerge in the driest soil. Most emergence failures were due to inadequate plant turgor at 7 percent moisture, fan-folding of shoots at 10 percent, and damping-off by species of *Fusarium* and *Penicillium* at 15 percent.

Table 2. Emergence (percent) of Stephens wheat 14 days after planting at 5-inch depth into warm (75 °F), moist (7, 10 or 15 percent water content, by weight) soil in the greenhouse; simulating a stubble-mulch tillage planting.

| Seed treatment and rate (fl oz/cwt) | Soil moisture (percent) | | | |
|---|---|---|---|---|
| | 7 | 10 | 15 | mean |
| Untreated | 11 | 58 | 48 | 39 |
| Dividend (0.5) | 39 | 71 | 81 | 64 |
| RTU Vitavax Thiram (5) | 23 | 79 | 83 | 62 |
| NuZone (0.75) | 32 | 52 | 63 | 49 |
| LSD (P=0.05) | 20 | ns | 20 | 12 |

Table 3. Emergence (percent) of fungicide-treated Stephens winter wheat planted at 3- or 5-inch depth into soils of three moisture contents (7, 10 or 15 percent) in the greenhouse.

| Days after planting | Seed treatment† | 3-inch planting depth | | | 5-inch planting depth | | |
|---|---|---|---|---|---|---|---|
| | | 7% | 10% | 15% | 7% | 10% | 15% |
| 7 | Dividend | 0 | 60 | 90 | 0 | 0 | 0 |
| | Raxil | 0 | 3 | 80 | 0 | 0 | 0 |
| 9 | Dividend | - | 90 | 100 | - | 57 | 90 |
| | Raxil | - | 67 | 87 | - | 10 | 80 |
| 11 | Dividend | 40 | 97 | 100 | 17 | 67 | 90 |
| | Raxil | 23 | 90 | 87 | 7 | 57 | 87 |
| 13 | Dividend | 57 | 97 | 100 | 43 | 67 | 93 |
| | Raxil | 40 | 90 | 87 | 27 | 73 | 90 |
| 21 | Dividend | 63 | 93 | 100 | 50 | 67 | 90 |
| | Raxil | 53 | 90 | 90 | 53 | 77 | 87 |

† Seed treatments were Dividend + Apron at the rate of 0.5+0.09 fl oz/cwt, or Raxil Thiram at 3.5 fl oz/cwt. Data were not collected where designated by “ - ”.

Emergence of Dividend-treated winter wheat seed from shallow planting depths in the field was several days earlier than for RTU Vitavax Thiram-treated seed during 1993 (Table 4). Addition of NuZone to either Dividend or RTU Vitavax Thiram caused emergence to be slower than for either of the primary treatments. Soil moisture at planting depth was not restrictive to germination. These effects were noted as early as one week

Table 4. Emergence† of winter wheat seedlings from 3-3.5 inch planting depth near Helix and Pendleton during 1993.

| | Days after planting at Helix‡ | | Days after planting at Pendleton§ | |
|---|---|---|---|---|
| Treatment (fl oz/cwt) | 10 | 16 | 8 | 14 |
| Control | 2.5 | 3.0 | 1.9 | 3.0 |
| Dividend (0.5) | 2.2 | 3.0 | 1.6 | 2.9 |
| Dividend (1) | 2.3 | 3.0 | 1.5 | 3.0 |
| Dividend + Apron (0.5+1) | 2.2 | 2.9 | 1.6 | 3.0 |
| Dividend + NuZone (0.5+0.75) | 1.3* | 3.0 | 1.0* | 2.7* |
| Dividend + NuZone (0.5+1.5) | 1.0* | 3.0 | 0.9* | 2.6* |
| Dividend + NuZone + Apron (0.5+0.75+1) | 1.2* | 3.0 | 1.1* | 2.9 |
| RTU Vitavax Thiram (5) | 1.5* | 2.9 | 0.9* | 2.7* |
| RTU + NuZone (5+0.75) | 0.9* | 2.8 | 0.6* | 2.0* |
| RTU + NuZone (5+1.5) | 0.5* | 2.5* | 0.5* | 2.1* |
| RTU + NuZone + Apron (5+0.75+1) | 0.9* | 2.8 | 0.5* | 2.4* |
| LSD (P=0.05) | 0.4 | 0.2 | 0.4 | 0.2 |

† Emergence ratings; 0 = <10 percent of seedlings emerged, 1 = 10-50 percent, 2 = 50-85 percent, and 3 = >85 percent. Data within each column differ from untreated seed when marked by an asterisk (*). Stand counts for Stephens wheat 25 days after planting were 17-21 seedlings/ft. of row near Pendleton and 17-24 seedlings/ft. of row near Helix: representative stand counts near Helix were 24.2 for Dividend + NuZone (0.5+1.5), 20.0 for Dividend (1.0) and the untreated control, 17.8 for RTU Vitavax Thiram, and 17.0 for RTU Vitavax Thiram + NuZone (5+1.5).
‡ Combined data for three varieties (Madsen, Rohde, and Stephens) of soft-white winter wheat.
§ Combined data for two varieties (Madsen and Stephens) of soft-white winter wheat.

after planting and, with the exception of the combination of RTU Vitavax Thiram and NuZone, were mostly dissipated after the second week. Seed treated with Dividend alone or Dividend + Apron emerged as quickly as untreated seed. Final stand counts did not differ among fungicide treatments near Pendleton, and were higher for Dividend than RTU Vitavax Thiram and control treatments near Helix.

Table 5. Emergence† of winter wheat seedlings from 4-5 inch planting depths near Arlington and Prosser during 1993.

| | Days after planting at Arlington‡ | | Days after planting at Benton City§ | | |
|---|---|---|---|---|---|
| Treatment (fl oz/cwt) | 15 | 22 | 14 | 21 | 34 |
| Control | 2.4 | 2.9 | 1.5 | 2.1 | 2.0 |
| Dividend (0.5) | 2.8* | 3.0 | 2.2* | 2.6* | 2.6* |
| Dividend (1) | 2.5 | 2.8 | 2.2* | 2.5 | 2.5* |
| Dividend + NuZone (0.5+0.75) | 1.4* | 2.6 | 1.4 | 1.8 | 2.1 |
| Dividend + NuZone (0.5+1.5) | 1.2* | 2.3* | 0.9* | 1.3* | 1.5* |
| RTU Vitavax Thiram (5) | 1.3* | 2.5 | 0.9* | 1.5 | 1.7 |
| RTU + NuZone (5+0.75) | 1.2* | 2.3* | 1.0 | 1.6 | 1.8 |
| RTU + NuZone (5+1.5) | 0.9* | 2.0* | 0.4* | 0.8* | 1.3* |
| LSD (P=0.05) | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 |

† Emergence ratings; 0 = <10 percent of seedlings emerged, 1 = 10-50 percent, 2 = 50-85 percent, and 3 = >85 percent. Data within each column differ from untreated seed when marked by an asterisk (*). Stand counts for Weston wheat 34 days after planting near Benton City were 2-7 seedlings/ft. of row (P<0.01; LSD=1.1): representative stand counts were 7.0 for Dividend (1.0), 5.2 for Dividend + NuZone (0.5+1.5), 4.7 for the control, 4.3 for RTU Vitavax Thiram + NuZone (5+1.5), and 2.3 for RTU Vitavax Thiram (5).
‡ Combined data for two varieties; Rohde and Stephens.
§ Combined data for Rohde and Weston.

Dividend-treated seed also emerged more quickly and RTU Vitavax Thiram-treated seed more slowly than untreated seed planted deeply (4-5 in.) into soil with 8-9 percent seed-zone moisture (Table 5). Supplementation of the primary fungicide with NuZone tended to delay emergence. Stand density was higher for seed treated with Dividend than RTU Vitavax Thiram near Benton City and was not assessed near Arlington.

Emergence was evaluated near Benton City and Ione under critically low soil moisture during a drought in 1994. There was no significant rainfall at either site for eight weeks after planting. Most soft-white winter wheat cultivars emerged very slowly at Benton City (6.6 percent soil moisture at planting depth), and failed to emerge at Ione (4.9 percent moisture at planting depth). A hard-red winter wheat (cv. Weston) began to emerge two weeks after planting at both sites.

Compared to untreated seed, emergence of Weston was enhanced by both Dividend and RTU Vitavax Thiram (Table 6). NuZone reduced the initial rate of emergence when applied with Dividend at Benton City but not at Ione. FloPro IMZ did not influence the rate of emergence when applied with RTU Vitavax Thiram. One of 19 soft-white cultivars (cv. Rod) emerged as well as cv. Weston near Benton City. Emergence of Weston near Ione was extremely slow and seed rot caused stands to be unacceptably sparse. The trial was abandoned after emergence data was collected.

Seed treatment fungicides were examined near Arlington (10 percent soil moisture at 4.5-in. planting depth), Echo (10 percent moisture at 3.5-in. depth) and Pendleton (15 percent moisture at 3-in. depth) during 1995. Emergence did not differ significantly among fungicide treatments at any location although it tended to be slower for treatments containing Raxil Thiram (with or without Gaucho) than either Dividend or RTU Vitavax Thiram near Echo and Pendleton (data not presented). Final stand counts were 0-10 percent near Arlington, 30-43 percent near Echo, and 84-100 percent near Pendleton (data not presented). Rain (0.25 in.) followed by rapid drying seven days after planting caused surface crusting near Arlington. Reasons for poor emergence at Echo were not apparent.

The influence of planting depth on emergence of fungicide-treated seed was examined near Pendleton during 1995. The experiment was performed under conditions of plentiful soil moisture (13 percent to 16 percent at planting depth). Emergence was predictably delayed by increasing planting depth (Table 7). Dividend enhanced the rate of emergence for seed planted at 1.1-in. depth. When placed at 2.8- and 4.1-in. depth, Raxil Thiram-treated seed with or without Gaucho had slower emergence than other treatments. Raxil Thiram reduced the rate of emergence for more than three weeks compared to untreated seed placed at 4.1-in. depth.

## DISCUSSION

Emergence of winter wheat in a stubble-mulch tillage system in the field and as a simulated system in the greenhouse was delayed and final stand density reduced by increasing planting depth, decreasing seed-zone moisture content, and surface crusting before emergence. Seed germination generally exceeded 95 percent at all except critically low soil water contents.

Seedling emergence in the field and greenhouse was often more rapid for seed treated with Dividend or Dividend + Apron compared to untreated seed or seed treated with RTU Vitavax Thiram, NuZone, or Raxil. Differences in emergence among treatments were as much as two days in the greenhouse and two weeks in the field. Improved emergence from Dividend treatment was observed at soil water contents ranging from sub-optimum to optimum for emergence. Dividend did not expedite emergence in several experiments, but in no instance did it delay emergence.

Final stand density differed among treatments in some of our field experiments. Dividend occasionally improved stand density and there was a potential for this fungicide to improve final stand density if surface crusting would have occurred between dates of emergence for treatments with the most rapid and slowest emergence. Rain two days after planting at Arlington during 1995, followed by rapid drying, caused crusting in all treatments before coleoptiles reached the surface. Dividend-treated seed did not emerge rapidly enough to prevent stand failure.

Table 6. Emergence† of Weston winter wheat seedlings from 4.5-5 inch planting depths near Benton City and Ione during 1994.

| | Days after planting | | | | | |
|---|---|---|---|---|---|---|
| | Ione | | | Benton City | | |
| Treatment (fl oz/cwt) | 16 | 23 | 36 | 13 | 21 | 34 |
| Control | 0 | 0.4 | 0.7 | 0.8 | 1.8 | 2.8 |
| Dividend (0.5) | 0.2 | 1.0 | 1.4* | 1.8* | 2.2 | 2.8 |
| Dividend (1) | 0.8* | 1.4 | 2.2* | 1.6* | 2.2 | 2.8 |
| Dividend + NuZone (0.5+0.75) | 0.2 | 1.0 | 1.4* | 1.0 | 2.0 | 3.0 |
| Dividend + Maxim (0.5+0.16) | 0.8* | 0.8 | 1.4* | 1.6* | 2.6* | 2.8 |
| RTU Vitavax Thiram (5) | 0.8* | 1.4 | 1.6* | 1.6* | 2.4 | 2.8 |
| RTU + FloPro IMZ (5+0.5) | 0.2 | 1.0 | 1.4* | 1.2 | 1.6 | 2.2 |
| LSD (P=0.05) | 0.7 | ns | 0.7 | 0.6 | 0.7 | ns |

† Emergence ratings; 0 = <10 percent of seedlings emerged, 1 = 10-50 percent, 2 = 50-85 percent, and 3 = >85 percent. Data within each column differ from untreated seed when marked by an asterisk (*).

Table 7. Emergence† of Rod winter wheat seedlings from three planting depths (1.1, 2.8, and 4.1 inches) near Pendleton during 1995.

| Treatment and rate (fl oz/cwt) | 1.1-inch | | 2.8-inch | | 4.1 inch | | |
|---|---|---|---|---|---|---|---|
| | 7‡ | 13 | 7 | 13 | 7 | 13 | 24 |
| Nontreated control | 69 | 83 | 30 | 88 | 2 | 56 | 63 |
| Dividend + Apron (1.0+0.09) | 91* | 100 | 21 | 86 | 0 | 50 | 58 |
| RTU Vitavax Thiram (6.0) | 65 | 90 | 19 | 83 | 0 | 48 | 56 |
| Raxil Thiram (3.5) | 59 | 86 | 8* | 82 | 2 | 36 | 46* |
| Raxil Thiram + Gaucho (3.5+2.0) | 70 | 95 | 6* | 91 | 0 | 43 | 51 |
| LSD (0.05) | 21 | ns | 16 | ns | ns | ns | 12 |

†Percentage of emerged seedlings from 15 seed planted per foot of row. Data within each column differ from untreated seed when marked by an asterisk (*).
‡Days after planting.

However, differences in stand density would have been likely if a similar crusting event had occurred 14 days after planting at Arlington or Benton City during 1993, or 7 to 10 days after planting at Pendleton during 1995.

RTU Vitavax Thiram had a variable effect on seedling emergence. This fungicide improved emergence from extremely dry soil at two field sites during 1995, but more generally had either no effect compared to untreated seed, or caused delayed emergence and/or reduced final stand density compared to treatment with Dividend. Although inhibitory effects have been reported, the sparcity of reports on this topic, and our experience, suggests that Vitavax Thiram neither inhibits nor stimulates emergence in most instances.

NuZone and FloPro IMZ also had variable effects on seedling emergence and stand density. These imazalil fungicides had either no effect or inhibited emergence and stand establishment in the field. In contrast, NuZone stimulated emergence in very dry soil in the greenhouse. Reasons for the discrepancy between results with dry soil in the greenhouse and field remain unknown. Our results with imazalil fungicides in the field are comparable to inhibitory effects described by others.

Raxil Thiram was evaluated with or without Gaucho insecticide at four sites during 1995. Raxil Thiram-treated seed tended to emerge more slowly than other treatments, particularly when seed was planted more than 3-in. deep. This may not be a problem under commercial practice because the Raxil Thiram label states that this fungicide is not recommended for seed planted deeper than 1.5- to 2-in. In semiarid regions with stubble-mulch fallow Raxil Thiram is likely to be used mostly for shallow-planted cereals such as spring wheat or barley. Surface crusting is not common with spring plantings. Gaucho did not modify emergence characteristics compared to the fungicide alone.

Reasons for poor emergence near Echo during 1995 were not clear. Seed-zone moisture may have been depleted by mixing moist and dry soil during planting, although this was not known to have occurred at Echo or other sites. The seed-zone water content at planting (10.1 percent) was not low enough to impede germination of wheat. It is more likely that high temperature dormancy impeded seed germination. Seed-zone temperature near Echo was 80 $^{o}$F at the time of planting. Seed dormancy is variable and typically occurs at temperatures above 68-77 $^{o}$F (Austin and Jones, 1975). Elongation of coleoptiles and emergence are also impeded when seed is planted into hot soil (Allan et al., 1962).

Combined effects of temperature, moisture, and seed characteristics apparently contributed to poor emergence near Benton City during 1994. Emergence was poor for four soft-white winter wheat cultivars (cvs. Gene, Madsen, Rohde, and Stephens), and marginally acceptable for the only hard-red winter wheat (cv. Weston) in the fungicide seed treatment trial. In an adjacent disease screening nursery only one (cv. Rod) of 19 soft-white winter wheat cultivars emerged as well as two hard-red wheat cultivars (cvs. Hatton and Weston) in the nursery. Differences in emergence did not appear to be related to coleoptile length or protein content, both of which are related to seedling vigor and emergence (Austin and Jones, 1975; Torres and Paulsen, 1982). Rod was the only cultivar screened for seed size and only the plumpest kernels were delivered from a commercial seed dealer for this test. Seed of Rod was retained between A.S.T.M. screen mesh sizes 6 (0.131-in. openings) and 7 (0.110 in.), while seed of other cultivars was mesh 7 through 8 (0.0937 in.). Seed of Rod weighed 0.058g/kernel compared to about 0.038g/kernel for other cultivars. Large seed size has been associated with improved emergence and seedling vigor in some tests. While seed-zone moisture was definitely limiting at planting, it clearly did not prevent germination and emergence of hard-red cultivars and Rod soft-white wheat. We suspect that interactions among seed size and soil temperature and moisture resulted in outstanding emergence of Rod during periods of high moisture and temperature stress during 1994. This hypothesis is supported by the absence of differences in emergence of non-sized seedlots of Rod (mesh 7-8; 0.038g/kernel) and 18 other soft-white winter wheat cultivars at five locations during 1995.

Poor emergence near Ione during 1994 was dominated by effects of drought on seed germination. Seed-zone moisture was well below that required for optimal germination of wheat. Nevertheless, the ability of hard-red winter wheat to germinate and emerge under these conditions was measurably higher than for soft-white winter wheat cultivars.

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## SUMMARY

Emergence of Dividend-treated seed over a range of soil moisture contents in the greenhouse was usually more rapid than for other fungicide treatments or untreated seed. Emergence in the field also tended to be superior for seed treated with Dividend in plantings made from 1- to 5-inches deep into soil with 5 to 17 percent seed-zone water content and 71 to 80 $^{o}$F temperature. RTU Vitavax Thiram had variable effects on seedling emergence. NuZone and Raxil Thiram generally delayed emergence when treated seed was planted at depths more than 2 inch. This research demonstrated that emergence of winter wheat planted deeply into subble-mulch fallow is often improved when seed is treated with Dividend compared to RTU Vitavax Thiram.

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