# Influence of Disease Severity and Environmental Conditions on Low Receptivity of Oats to Crown Rust

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**ABSTRACT**

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Low receptivity, a major component of slow rusting, is characterized by fewer pustules on slow rusting cultivars than on fast rusting types. Slow rusting and fast rusting cultivars of oats were quantitatively inoculated with crown rust urediospores. In the growth chamber, low receptivity was expressed when about four pustules per square centimeter developed on the slow rusting cultivar but not at greater densities, ie, six to eight pustules per square centimeter. Spore germination and appressoria formation were not correlated with low receptivity. Spores that settled on the leaves quickly (1 min) were not as infective as lighter spores that settled more slowly (2 min). When comparable quantities of spores (about 50/cm$^2$) germinated on leaves, the slow rusting cultivar had 50- to 65-fold fewer pustules in the field than in the growth chamber. The fast rusting cultivar had about the same number of pustules per square centimeter in the field and growth chamber.

"Slow rusting," a form of horizontal resistance, is characterized by a low percentage of disease (1–30%) throughout the epidemic (7). "Fast rusting" is characterized by rapid disease development that results in 80–90% infection by the end of the epidemic. Slow rusting is composed of several factors. One of these is low receptivity, a term used to indicate that fewer pustules occur on slow rusting than on fast rusting cultivars. Although the term "low receptivity" does not have etymonic characteristics, it most nearly describes the component of slow rusting that we examined. Low receptivity of oats, which has been reported using various terms, has been observed in several host-pathogen combinations (3,5,6,8,9).

The slow rusting characteristic of oats (*Avena sativa* L.) was first reported in 1889 (10), but very little is known about the nature of this unique type of resistance. We conducted three types of experiments to investigate the nature of one component of slow rusting, that is, low receptivity. Our objectives were to determine whether factors responsible for low receptivity occur before or after host penetration, to determine the percentage of infection required to overcome low receptivity, and to compare the effects of growth chamber and field conditions on low receptivity.

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## MATERIALS AND METHODS

**Growth chamber tests.** Seeds of the oat cultivars Red Rustproof-14, CI 4876 (slow rusting), and Fulghum, CI 708 (fast rusting), were planted in 500-ml plastic boxes that contained sandy loam, peat, and perlite (2:1:1) with 4 g of Osmocote (14% nitrogen, 14% phosphoric acid, 14% potassium) mixed with each liter of soil. Seeds were planted in a row on one side of the box, and seedlings were thinned to five per box when the plants were about 2 wk old. Each test consisted of four boxes of each cultivar, containing five plants per box.

When plants were 25–30 days old (fifth leaf stage), they were inoculated by using a settling tower similar to that described by Eyal et al (2). Plants were arranged in a horizontal position and the tips of the fourth leaf were taped to the bottom of the settling tower. Taping was done to keep leaf blades flat so that each leaf would be equally exposed to spores settling in the tower. In some experiments, 1 mg of the spores of *Puccinia coronata* Cda. var. *avenae* Fraser & Led. was discharged into the tower with a $CO_2$ gun and allowed to settle for 1 min. By this procedure, 70–100 spores were deposited per square centimeter of leaf surface. In other tests, 1 mg of spores was allowed to settle for 30–45 sec, which resulted in deposition of 30–50 spores per square centimeter of leaf surface. In paired tests to determine the number of spores required to overcome low receptivity, one group of plants was exposed to 1 mg of spores for 1 min and the other group was exposed to 1 mg for 2 min. Spores freshly collected from Fulghum nurse plants were used throughout the study.

Inoculated plants were maintained in a dew chamber for 12–14 hr; the dew period was 8–10 hr, and the temperature ranged

**Table 1.** Pustules on slow rusting Red Rustproof and fast rusting Fulghum oats inoculated with spore concentrations of *Puccinia coronata* in the growth chamber

| Cultivar | Spores deposited on leaves (no./cm$^2$) | Spore germination (no./cm$^2$) | Appressoria (no./cm$^2$) | Pustules[a] (no./cm$^2$) |
|---|---|---|---|---|
| | | **Test 1** | | |
| Red Rustproof | 29.4 | 10.5 | 5.3 | 2.5 |
| Fulghum | 33.9 | 11.9 | 6.0 | 4.3 |
| | | **Test 2** | | |
| Red Rustproof | 54.5 | 19.1 | 12.3 | 1.2 |
| Fulghum | 38.6 | 17.2 | 6.9 | 2.3 |
| | | **Test 3** | | |
| Red Rustproof | 90.6 | 42.1 | 23.2 | 2.0 |
| Fulghum | 77.8 | 32.1 | 15.2 | 4.0 |

[a] Each mean was calculated from four replications consisting of four plants per replicate. The levels of significance ($P$ value) between cultivars in tests 1, 2, and 3 were 0.02, 0.0004, 0.0001, respectively.

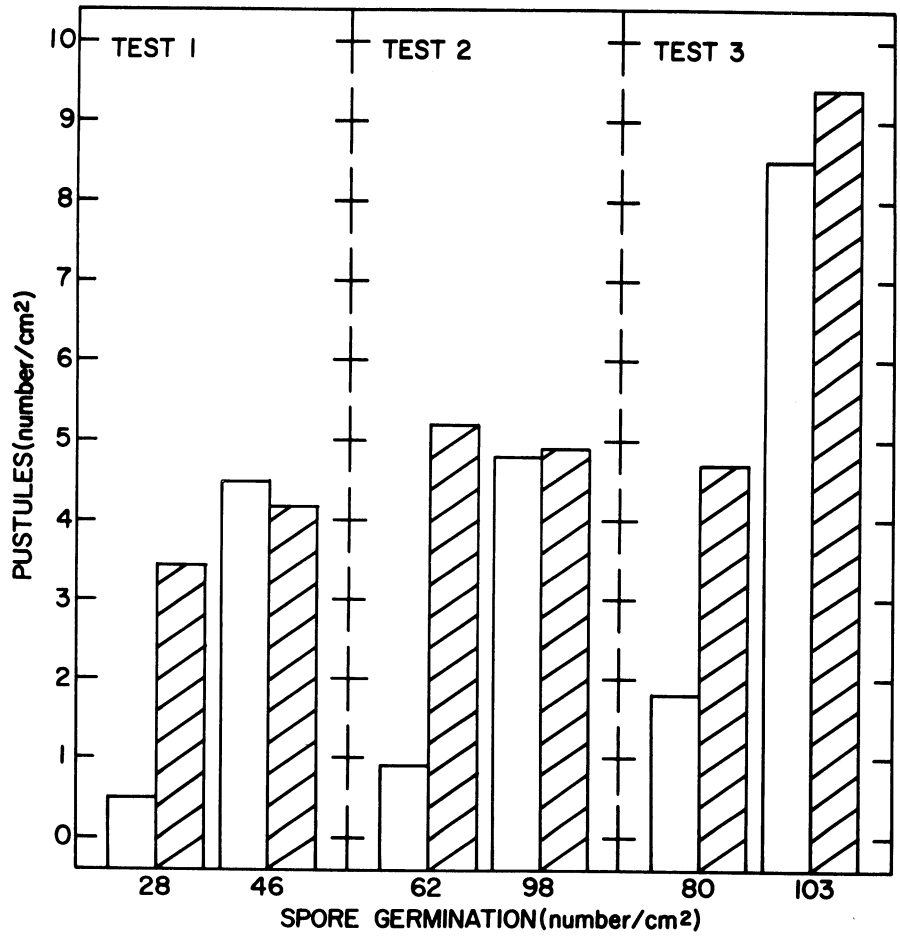


**Fig. 1.** Influence of the number of pustules per square centimeter on low receptivity of oats to crown rust in the growth chamber. In each test, 1 mg of spores was allowed to settle for 1 min (low inoculum level, the 2 bars on the left) or 2 min (high inoculum level, the 2 bars on the right). □ = slow rusting cultivar; ▨ = fast rusting cultivar. There were significant differences ($P = 0.01$) between cultivars in the low inoculum treatments but not in the high inoculum treatments.

**Table 2.** Pustules[a] of *Puccinia coronata* observed on three oat cultivars[b] in the field

| Test | Spore germination[c] (no./cm²) | Pustules (no./cm²) Red Rustproof | Burt | Fulghum |
|---|---|---|---|---|
| 1 | 38 | 0.03 | 0.19 | 0.63 |
| 2 | 42 | 0.02 | 0.12 | 1.20 |
| 3 | 65 | 0.03 | 1.18 | 1.65 |

[a] Each mean was calculated from three replications consisting of 10 plants per replicate.
[b] Red Rustproof, slow rusting; Burt, intermediate slow rusting; Fulghum, fast rusting.
[c] There was no spore germination × cultivar interaction. Mean values for the three cultivars are presented.

from 14 to 18 C. Plants were then transferred to a growth chamber having a 14-hr photoperiod; the temperature ranged from 14 C during the dark period to 25 C during the light period. The light quantity in the plant area was $2.4 \times 10^4$ lux.

About 24 hr after inoculation, one leaf from each box was removed and sprayed with acid fuchsin and cotton blue in 50% ethanol (1). Midveins were removed and leaf halves were taped to microscope slides. Leaves were examined at ×100 magnification by passing high intensity light from a substage lamp through them. This method was used to determine the number of spores per square centimeter, the number of germinated spores, the number of appressoria formed, and the number of appressoria that developed penetration pegs. The number of pustules per square centimeter was determined 10–12 days after inoculation.

**Field tests.** We used the spore settling tower to inoculate three cultivars of oats (Red Rustproof, Fulghum, and Burt) in the field to determine the effects of the environment on low receptivity. The quantity of spores deposited on leaves in field tests was similar to that in the paired tests. Inoculations were made at 2000 hours when the wind speed was low. Five inoculations were made between 23 and 30 March 1976.

These tests were conducted in an isolated area devoid of rust infection. Each test consisted of three replications of 10 plants per replicate. One leaf was taken from each plant 15 days after inoculation, and the number of pustules was counted.

## RESULTS AND DISCUSSION

Three of the 17 tests were selected to represent a range in the number of spores deposited on leaves (Table 1). More spores germinated and more appressoria developed on Red Rustproof in tests 2 and 3 than in test 1, but more pustules per square centimeter were observed on Red Rustproof in test 1.

The number of spores deposited, spore germinations, and appressoria formation were not correlated with the number of pustules. This trend was observed throughout the study when less than 20% disease developed on cultivars with low receptivity. It therefore appears that low receptivity in Red Rustproof oats is expressed after stomatal penetration. A similar observation was made by Heagle and Moore (3). Kochman and Brown (4,5), however, observed that significantly fewer appressoria produced penetration pegs on slow rusting cultivars than on fast rusting cultivars. These workers suggested that differences in penetration frequency may be a component of slow rusting (low receptivity).

Our observations and those of Heagle and Moore (3) do not agree with those of Kochman and Brown (4,5). In some interactions between *P. coronata* and *A. sativa*, penetration frequency apparently influences low receptivity, but in other such interactions, low receptivity is expressed after stomatal penetration. The latter supposition is supported by the fact that we did not observe statistical differences between cultivars in the number of spores that germinated, appressoria formation, and appressoria that produced penetration pegs.

When the number of pustules on the cultivar with low receptivity was much $>4/cm^2$, there was no significant difference in the number of pustules per square centimeter on fast rusting types and those with low receptivity (Fig. 1). Conversely, when <4 pustules per square centimeter developed on the cultivar with low receptivity, there were always significantly fewer pustules on this cultivar than on the fast rusting type. In the growth chamber, low receptivity was not expressed when >4 pustules developed per square centimeter. Four pustules per square centimeter is equivalent to about 20% disease severity.

Different spores in the population caused different amounts of infection on the slow rusting cultivar. High infectivity in the paired tests (Fig. 1) was obtained by allowing 1 mg of spores to settle on the leaves for 2 min; low infectivity was obtained by allowing 1 mg of spores to settle for 1 min. Differences in the number of spores that germinated in the low and high rate treatments were small (<twofold), but the differences in the number of pustules on the slow rusting cultivar were large (ninefold in test 1 and sixfold in test 2). We therefore assumed that the spores that settled during the first

minute were not as infective as the lighter spores deposited on the leaves during the second minute of the 2-min exposures.

The number of spores that germinated on plants in the growth chamber (Table 1) was comparable to that on plants in the field (Table 2). Numbers of pustules on the fast rusting cultivar were similar under field and growth chamber conditions (tests 2 and 3, Tables 1 and 2), but the slow rusting cultivar had 50- and 65-fold fewer pustules when grown in the field than when grown in the growth chamber. Moreover, Burt exhibited an intermediate degree of receptivity in the field (7) but did not express low receptivity in the greenhouse and growth chamber. Environmental conditions therefore exert a pronounced effect on the low receptivity of oats to crown rust. The infection threshold is much higher in the field than in the growth chamber. Therefore, field-grown plants appear to have fewer susceptible sites than those grown in the growth chamber.

The large differences in the low receptivity of the slow rusting cultivar under growth chamber and field conditions indicate the magnitude of the influence of field conditions on the expression of low receptivity. Under field conditions, low receptivity can be assessed under a wide range of spore loads. The useful range in the number of spores applied under artificial conditions is narrow, however, and must be chosen carefully if one expects to adequately assess the degree of low receptivity.

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