# Effects of Fertilizers on Slow Rusting in Wheat

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## ABSTRACT

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In an NPK factorial experiment, Marquis wheat rusted rapidly with *Puccinia graminis* f.sp. *tritici* (wheat stem rust pathogen) and *P. recondita* f.sp. *tritici* (wheat leaf rust pathogen), Lee rusted moderately rapidly with both pathogens, and Thatcher rusted slowly with the stem rust pathogen and rapidly with the leaf rust pathogen. The interaction of cultivars with fertilizer treatments was not significant. $NH_4NO_3$ enhanced leaf rust development in 1975, and stem rust development in 1979, but did not affect rust development in other years as indicated by area under the disease progress curve. $P_2O_5$ enhanced stem rust development in 1977, but did not affect stem rust or leaf rust development in any of the other 5 yr of the study. $K_2O$ enhanced leaf rust development in 1973 and stem rust development in 1979, but did not affect either rust in other years.

Slow rusting in wheat infected with the stem or leaf rust pathogens has been demonstrated to be a highly heritable trait (3,7), but its usefulness in the control of the rusts depends in large part on how stable it is when the slow rusting cultivars are grown under various environmental conditions. Fertilizers constitute an environmental factor that varies greatly from field to field and influences the susceptibility of plants. In general, fertilization with nitrogen alone tends to increase the susceptibility of plants to the rusts, whereas fertilization with phosphorus or potassium alone tends to decrease susceptibility. When these elements are used in a balanced fertilization program, phosphorus and potassium tend to overcome the adverse effects of nitrogen. The effects of fertilization on stem and leaf rusts have been summarized by Stakman and Aamodt (8), Chester (2), and more recently by Király (4) and Capetti et al (1). The objectives of this study were to evaluate the slow rusting characteristics of three cultivars in an NPK factorial experiment.

## MATERIALS AND METHODS

A field at Rosemount, MN, in which a factorial experiment with $NH_4NO_3$, $P_2O_5$, and $K_2O$ had been established in 1959 and continued annually, was used throughout. Corn, alfalfa, and oats have been grown on the field. During the 2 yr preceeding these experiments, the field was not fertilized and was planted with oats. The fertilized plots were 7.7 × 19 m and the treatments were randomized with four replicates. Each year 363 kg of $NH_4NO_3$, 312 kg of $P_2O_5$, and 335 kg of $K_2O$ per hectare were scattered by hand on the appropriate plots before planting, and the field was disced. Spring wheat (*Triticum aestivum* L.) cultivars Lee, Marquis, and Thatcher each were planted in 2.4-m-wide strips across each fertilizer plot at the rate of 90 kg of seed per hectare. Planting was done during the last week of April or the first week of May, the normal planting time for this area. Weeds were controlled with propachlor (2-chloro-*N*-isopropylacetanilide) and 2,4-D (2,4-dichlorophenoxyacetic acid). The entire experimental field was surrounded with a 6.1-m-wide border of Marquis wheat.

The wheat cultivars were chosen for study because they are susceptible to the races of *Puccinia graminis* Pers. f.sp. *tritici* and *P. recondita* Rob. ex Desm. f.sp. *tritici* studied, but they differ in the rate at which they rust: Marquis rusts rapidly with both pathogens, Lee rusts moderately rapidly with both pathogens, and Thatcher rusts slowly with the stem rust pathogen and rapidly with the leaf rust pathogen.

In 1973, 1974, and 1975 leaf rust caused by *Puccinia recondita* f.sp. *tritici* developed in the plots from naturally occurring inoculum. Races UN 2 and UN 17 were the most common races in the area. Stem rust was not evaluated because leaf rust was so severe that stem rust did not develop appreciably.

In 1976, 1977, and 1979 the plots were inoculated with *P. graminis* f.sp. *tritici* and leaf rust was prevented from developing by spraying 2-wk-old plants and the ground around them with a solution of triazbutil (4-butyl-4*H*-1,2,4-triazole) (Indar®, Rohm and Haas Co., Philadelphia, PA 19105) in water at the rate of 877 ml per hectare. Infection with *P. graminis* f.sp. *tritici* was initiated by spraying freshly collected urediospores of race 15B2-TLM, a race that commonly occurs in this part of Minnesota, suspended in Soltrol® (Phillips 66, Bartlesville, OK 74003), uniformly over each plot. The plants were inoculated when in the early boot growth stage. The border plants around the field also were inoculated.

Rust severity was evaluated once each week beginning about 1 wk before inoculation. After the disease appeared, rust severities were evaluated for an additional 3–5 wk with the aid of the modified Cobb scale (5). Rust severity data obtained in each plot were converted to area under the disease progress curve (AUDPC) with the aid of the computer program used by Skovmand et al (7). AUDPC, an indication of both the amount of rust present during the growing season and the rate at which it developed, was used to indicate the slow rusting characteristic of the cultivars in the various fertilizer treatments. Analysis of variance was used to help interpret the AUDPC values in the various treatments. When the analysis of variance indicated that the fertilizer treatments had a significant effect on rust development, individual fertilizer effects were studied by comparing the average AUDPC values from all plots that received the fertilizer with values from all that did not.

## RESULTS

There was no statistically significant fertilizer × cultivar interaction in any of the years of the test, which indicates that the relative susceptibilities of the cultivars to the rusts were not changed by the fertilizer treatments. In 1973, 1974, and 1975 leaf rust developed about equally in Marquis and Thatcher, as indicated by the nonsignificant average values for AUDPC, but it was significantly less severe in Lee (Table 1). In 1976, 1977, and 1979 stem rust developed about as expected: for Thatcher the average value for AUDPC was 321 or lower, for Lee it was 640 or lower, and for Marquis it was 890 or lower (Table 1). These differences in the cultivars were statistically significant ($P = 0.01$) each year.

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TABLE 1. Average areas under the disease progress curve[a] for Marquis, Lee, and Thatcher wheats grown in an NPK factorial fertilization experiment and infected with *Puccinia recondita* f.sp. *tritici* (leaf rust pathogen) and *P. graminis* f.sp. *tritici* (stem rust pathogen)

| Disease and fertilizer[b] treatments | 1973 | | | 1974 | | | 1975 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Marquis | Lee | Thatcher | Marquis | Lee | Thatcher | Marquis | Lee | Thatcher |
| Leaf rust | | | | | | | | | |
| N | 827 | 588 | 891 | 1,143 | 936 | 1,398 | 1,008 | 892 | 1,265 |
| P | 627 | 462 | 898 | 1,168 | 1,016 | 1,443 | 674 | 417 | 647 |
| K | 685 | 435 | 720 | 1,201 | 824 | 1,488 | 970 | 493 | 923 |
| NP | 738 | 502 | 793 | 1,223 | 971 | 1,328 | 975 | 733 | 1,062 |
| NK | 653 | 418 | 768 | 1,233 | 866 | 1,368 | 1,095 | 938 | 1,326 |
| PK | 753 | 418 | 780 | 1,303 | 809 | 1,443 | 923 | 529 | 867 |
| NPK | 843 | 400 | 760 | 1,143 | 703 | 1,202 | 855 | 589 | 1,057 |
| None | 678 | 523 | 728 | 1,348 | 1,092 | 1,488 | 734 | 464 | 715 |
| Average | 750 | 468 | 789 | 1,220 | 903 | 1,382 | 904 | 632 | 995 |
| Stem rust | 1976 | | | 1977 | | | 1979 | | |
| N | 741 | 654 | 428 | 624 | 353 | 192 | 910 | 687 | 342 |
| P | 664 | 412 | 173 | 669 | 385 | 182 | 892 | 653 | 265 |
| K | 708 | 664 | 341 | 577 | 209 | 122 | 884 | 705 | 258 |
| NP | 804 | 683 | 260 | 641 | 354 | 208 | 954 | 705 | 387 |
| NK | 732 | 621 | 309 | 596 | 285 | 181 | 901 | 684 | 366 |
| PK | 639 | 440 | 163 | 631 | 295 | 173 | 875 | 600 | 314 |
| NPK | 746 | 659 | 241 | 641 | 311 | 199 | 875 | 579 | 356 |
| None | 776 | 713 | 206 | 622 | 336 | 164 | 831 | 622 | 278 |
| Average | 726 | 606 | 265 | 621 | 316 | 177 | 890 | 640 | 321 |

[a] Data based on four replicates each year. Statistically significant differences were: cultivars each year $P=0.01$; fertilizers 1973, $P=0.05$; 1975, $P=0.01$; 1977, $P=0.10$; 1979, $P=0.05$. Areas under the disease progress curve are in arbitrary units and were calculated from three points on the disease progress curve in 1973, 1976, 1977 and 1979, from five points in 1974, and from four points in 1975. In 1973–1975 the disease was primarily leaf rust, but in 1976–1979 it was only stem rust.

[b] Fertilized annually with: $NH_4NO_3$, 363 kg/ha; $P_2O_5$, 312 kg/ha; and $K_2O$, 335 kg/ha.

The effect of fertilizers on slow rusting with both pathogens varied with the year and the fertilizer applied. In the leaf rust tests, the fertilizer treatments significantly altered the development of leaf rust, as indicated by the average values of AUDPC, in 1973 and 1975, but not in 1974 (Table 2). In 1973 treatment of plots with $K_2O$ significantly ($P = 0.05$) reduced the average value of AUDPC, but $NH_4NO_3$ and $P_2O_5$ did not significantly influence leaf rust development. In 1975 treatment of plots with $NH_4NO_3$ significantly ($P = 0.05$) increased the average value of AUDPC, but $P_2O_5$ and $K_2O$ had no effect on leaf rust. In the stem rust tests, there was no significant effect of fertilizer on stem rust development in 1976, but there was in the other 2 yr (Table 2). In 1977 treatment of plots with $P_2O_5$ significantly ($P = 0.05$) increased the average value of AUDPC and treatment of plots with $K_2O$ decreased ($P = 0.05$) AUDPC, but $NH_4NO_3$ did not significantly influence AUDPC. In 1979 treatment of plots with $NH_4NO_3$ increased ($P = 0.05$) the average value of AUDPC, whereas $P_2O_5$ and $K_2O$ had no significant effect.

TABLE 2. Effects of fertilization with N, P, or K on average area under the stem rust or leaf rust disease progress curves in wheat plots in different years.

| Fertilization | | Area under disease progress curve[a] | | | | | |
|---|---|---|---|---|---|---|---|
| Material | Rate (kg/ha) | 1973 | 1974 | 1975 | 1976 | 1977 | 1979 |
| $NH_4NO_3$ | 363 | 681 | 1,118 | 983* | 573 | 383 | 645* |
| | 0 | 657 | 1,219 | 704 | 492 | 363 | 588 |
| $P_2O_5$ | 312 | 679 | 1,146 | 788 | 490 | 388* | 621 |
| | 0 | 659 | 1,191 | 908 | 574 | 338 | 612 |
| $K_2O$ | 355 | 634* | 1,124 | 897 | 522 | 349* | 606 |
| | 0 | 704 | 1,213 | 799 | 542 | 377 | 627 |

[a] For each year the data are average values across all cultivars in plots that received or did not receive the indicated ferilizer. An asterisk on a data pair indicates that the effect of the fertilizer was statistically significant ($P = 0.05$). For data pairs without asterisk, the differences were not significant.

## DISCUSSION

It is possible that the failure to detect a significant effect of fertilizer treatment on leaf and stem rust development may have been due to a fairly high level of fertility in the field when the experiment was started. An effort was made to obtain a field that was low in fertility by using one in which individual plots had been fertilized with N, P, or K each year for many years. In addition, during the 2 yr previous to the experiments, the field was not fertilized at all and was planted with oats. Observations on plant growth and yields indicated that the plots did differ in fertility. In the plots that received the combined nitrogen-phosphorus and potassium treatment, the plants were deep green in color and were about 100 cm tall at maturity, whereas in the nonfertilized plots, the plants were light green in color and about 76 cm tall. The annual yields were 269–405 kg/ha more in the fertilized plots than in those not fertilized.

This report confirms previous observations that Lee rusts moderately rapidly with *P. graminis* f.sp. *tritici* and *P. recondita* f.sp. *tritici*, Marquis rusts rapidly with both pathogens, and Thatcher rusts slowly with stem rust pathogen, but rapidly with leaf rust pathogen (3,7). The slow rusting characteristics of these cultivars were maintained throughout the 3 yr of tests with each rust, in an NPK factorial experiment. The interaction of cultivars and fertilizers was nonsignificant, indicating that the fertilizer treatments had similar effects on all three cultivars.

The development of leaf and stem rusts was influenced by the fertilizer treatments, although the treatments did not significantly affect the slow rusting traits of the cultivars. The effect of the fertilizers was not consistent from year to year. $NH_4NO_3$ usually did not influence the development of the rusts, but it caused leaf rust to be more severe in 1975 and stem rust to be more severe in 1979. $P_2O_5$ generally did not influence the development of the rusts, but in 1977 it increased the severity of stem rust. $K_2O$ usually did not influence the development of the rusts, but it did cause leaf rust to be less severe in 1973 and stem rust to be less severe in 1979. It was impossible to predict what fertilizer would affect rust development in a particular year.

The amounts of each fertilizer applied to the plots were higher than is recommended for tall spring wheat cultivars in Minnesota, but they were applied to provide contrasting fertility effects. The data suggest that under customary fertility practices the slow rusting characteristics of cultivars would be little affected. Furthermore, the effect of a fertilizer, when it had an influence, was not great, and probably would have had even less effect under normal fertilization practices.

While the data presented here for slow rusting and by Shaner and Finney (6) for slow mildewing suggest that the expression of this type of resistance is not seriously affected by soil fertility, not many cultivars have been tested. I tested three and Shaner and Finney tested two. It would be worthwhile to test a number of different cultivars or lines of wheat to determine how universal our conclusions might be. Similar experiments should also be made with barley, oats, and corn.

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