Puccinia graminis Development in North America During 1986

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ABSTRACT

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Wheat stem rust was unusually severe in 1986, more so than in any of the last 20 yr. The frequency of virulence/avirulence phenotypes identified in 1986 was similar to other recent years. In contrast, oat stem rust (a similar disease) was less severe than normal, indicating that the favorability of the environment for stem rust development was near normal for both diseases. The more severe wheat stem rust development in the southern Great Plains was due to a severe epidemic in a small area along the Texas Gulf Coast during the winter that generated inoculum that was transported northward. An additional area of overwintering stem rust occurred on susceptible winter wheat cultivars in western North Dakota that resulted in abnormally severe disease in that area.

Puccinia graminis Pers. f. sp. *tritici* has been an important pathogen of wheat in much of the Great Plains of North America (4). Since 1954, however, no major epidemic of regional importance has occurred other than local epidemics such as the one in the Nebraska panhandle in 1965 (6,7). The lack of regional epidemics has been due mainly to the widespread use of resistant cultivars; however, a number of cultural practices have also had an effect (6,7). Removal of barberry reduced variability in the pathogen population and eliminated aeciospores as a source of inoculum in the northern Great Plains (5). The pathogen generally overwinters south of the 30th parallel of North America. Rust during the winter is limited to sporulating and nonsporulating uredia on fall-sown wheat along the Gulf Coast. Depending on the severity of the winter, stem rust usually starts increasing along the Gulf Coast in March and spreads northward to the Canadian border by early July (6). This disease spread has been monitored annually by personnel of the Cereal Rust Laboratory for about 65 yr (8).

The severity of a stem rust epidemic is determined by the virulence of the pathogen, resistance of the host, favorableness of the environment, and time available for disease development. Host resistance changes as new cultivars are introduced and others decrease in frequency. The changing of cultivars is a gradual process, and often, successive cultivars are related in terms of resistance genes. Most cultivars are grown for 5–10 yr, although a few are never grown to any extent and a few may last over 15 yr. Virulence shifts in the North American

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pathogen population have occurred on the average of 1 in 8 yr since the late 1960s. These changes have occurred in the most common phenotype and have involved the addition of a single gene for virulence. These changes have required 1–4 yr to become the predominant phenotype after they were first detected (A. P. Roelfs, *unpublished*). Thus, for wheat stem rust, changes in resistance and virulence are generally gradual over a number of seasons.

The environment varies between years and between days and locations within years. The eastern Great Plains is generally more favorable for both wheat growth and stem rust development than the western Great Plains (6). The major difference in disease levels between years is the amount of time stem rust has to develop. Because wheat maturity varies only a few days between years in most locations, the difference in epidemic length is due to the difference in date of disease onset (6,7,10). This paper shows the variation of the 1986 data from the mean observations and examines the probable causes and the potential long-term effects.

MATERIALS AND METHODS

Fields surveys (8) were made over a 10,000-km route covering the Great Plains of the United States. The surveys followed a preselected, generally circular route through areas where small-grain cereals are important and rust historically has been a problem. Checks for the presence of rust were made at commercial fields each 32 km or at the first field thereafter. Additional checks were made at experimental nurseries and wheat trap plots along the route. Whenever rust was observed, collections were made and taken to the laboratory for virulence/avirulence determination (9). In 1986, surveys were made in the following areas: southern Texas (early April); northern Texas (late April); Oklahoma and Kansas (mid-May); Nebraska and South Dakota (mid-June); Minnesota, eastern Montana, North Dakota, and northern South Dakota (early July); and Minnesota, eastern Montana, and North Dakota (early August).

RESULTS

During the early April survey of south Texas, the incidence (Table 1) and severity of the cereal rusts of small grains was near normal. Survey data indicated there was more stem rust than usual on wheat planted in November and December (D. L. Long, *unpublished*). Generally, stem rust is limited to the October plantings because infection normally occurs before mid-November. Wheat that emerges in December generally is not infected because of the unfavorably low nighttime temperatures. In mid-April, we were made aware of about 1,100 ha of wheat just south of Houston, TX, that was killed by stem rust. This was an area where rice is usually grown. In late April, wheat stem rust was present in most fields sampled across north central Texas and as far west as Abilene and Wichita Falls.

The date of wheat stem rust detection (onset) in north central Texas was earlier than normal but not as early as the 63-yr record (Fig. 1). In late May, stem rust was present as far north as Lincoln, NE. In this area, the observed date of onset was earlier than the 63-yr mean (Fig. 1) by 12 days. Wheat stem rust incidence and severity were also greater than normal (20-yr mean), and the date of onset approached that for epidemic years (Table 2). In northern Kansas, adequate disease developed in a few fields of some susceptible cultivars to cause severe (10–100%) losses. Generally, statewide conditions and crop maturity were such that only light (trace to 1%) losses were incurred. Most Nebraska growers planted highly resistant cultivars, and little damage occurred. By late June, rust was widespread across the spring wheat area of Minnesota, North Dakota, and South Dakota.

The field survey in early July showed

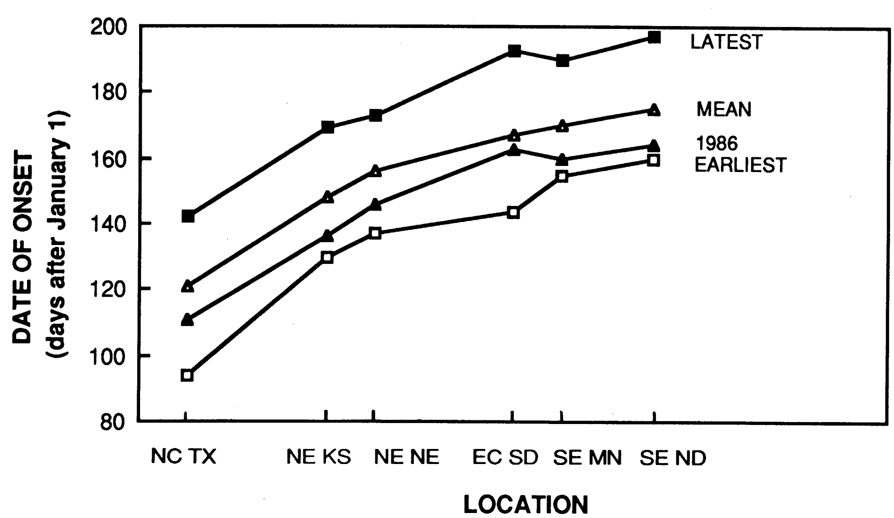

Fig. 1. The earliest, mean, latest, and 1986 onset date (expressed as number of days afer January 1 when first observed) for wheat stem rust in six Great Plains areas: NC TX = area around Dallas, TX; NE KS = area around Manhattan, KS; NE NE = area around Lincoln, NE; EC SD = area around Brookings, SD; SE MN = area around St. Paul, MN; and SE ND = area around Fargo, ND.

Table 1. Number of collections of wheat and oat stem rust made in Texas during recent years

Year	Wheat stem rust	Oat stem rust
1965	80	30
1966	43	5
1967	39	18
1968	87	51
1969	75	32
1970	51	18
1971	74	35
1972	85	45
1973	90	69
1974	78	78
1975	35	156
1976	60	108
1977	22	135
1978	30	131
1979	16	116
1980	2	162
1981	25	207
1982	13	238
1983	53	179
1984	23	58
1985	45	145
1986	95	64
Mean	51	100

Table 2. Comparison of the observed dates of wheat stem rust onset in eight selected years of severe epidemics and losses compared with 1986 at five northern locations

Year[a]	Northeast Kansas	Southeast Nebraska	East central South Dakota	Southeast Minnesota	Southeast North Dakota
1923	31 May	6 June	24 June	22 June	1 July
1925	25 May	8 June	15 June	17 June	15 June
1927	27 May	7 June	14 June	22 June	20 June
1929	5 June	5 June	20 June	20 June	21 June
1935	10 May	6 June	13 June	13 June	24 June
1937	2 June	30 May	12 June	11 June	12 June
1953	27 May	3 June	9 June	4 June	9 June
1954	28 May	29 May	11 June	7 June	11 June
Mean	27 May	4 June	15 June	15 June	19 June
1986	16 May	26 May	12 June	19 June	13 June

[a] Data from 1923–1964 from Hamilton and Stakman (1).

an increasing incidence and severity of stem rust west of the Missouri River in North Dakota and South Dakota. This is unique in our surveys (at least since 1965) because rust incidence and severity usually decrease toward the west because of decreasing precipitation and general direction of prevailing winds that are important in long-range dispersal of inoculum. The greatest severities in this area were confined to the winter wheats, and generally, infections were scattered over the entire plant with the oldest lesions often within 1–2 in. of the ground. The disease was often in fields that had surface residue from last season's wheat crop, and in some fields, obvious foci up to 1 m in diameter were observed. Surface residue indicates that tillage has left seed near the surface, where with adequate moisture, volunteer plants may develop in the summer and provide a potential green bridge between crops (August to September). Trap plots of the susceptible spring wheat cultivar Baart (headed to anthesis) had only a trace severity (confined to the flag leaf) with incidences of less than 1%, whereas susceptible cultivars of winter wheat had severities of 30–60% and incidences of over 90% (oldest infections at or near ground level).

Since 1965, there have been six North Dakota counties where a susceptible cultivar of wheat has been grown annually in relatively large plots (1 × 10 m). The severity and incidence of stem rust for each of these areas over the 21-yr period is shown in Table 3. Cass County is in east central North Dakota with nurseries at Cassleton and Fargo. The earliest report of disease is often made by North Dakota State University staff. Data from areas near inoculated plots was excluded. Foster County is in central North Dakota, and both irrigated and dryland plots are grown at Carrington. Golden Valley County borders Montana in the west central area, and plots are near Beach. Williams County is in northwestern North Dakota with plots at Williston. Cavalier County is in northeastern North Dakota where the cooler and wetter summers provide for extensive commercial planting of durum wheat. The other stations are in primarily a hard red spring wheat area, but some durum wheat is grown in Ward County. The largest area of winter wheat has been grown in the southwestern North

Table 3. Comparison of wheat and oat stem rust diseases in six North Dakota counties for the last 21 yr

	Wheat stem rust		Oat stem rust		Wheat stem rust		Oat stem rust		Wheat stem rust		Oat stem rust	
Year	Date	Sev/Incid[a]	Date	Sev/Incid	Date	Sev/Incid	Date	Sev/Incid	Date	Sev/Incid	Date	Sev/Incid
	Cass County				**Golden Valley County**				**Williams County**			
1965	21 Jun.	N/A	26 Jul.	N/A	12 Jul.	N/A	11 Aug.	N/A	15 Jul.	N/A	–[b]	–
1966	15 Jul.	N/A	22 Jul.	N/A	–	–	–	–	–	–	–	–
1967	2 Aug.	N/A	16 Aug.	N/A	–	–	–	–	–	–	–	–
1968	29 Jul.	N/A	12 Aug.	N/A	24 Jul.	N/A	–	–	–	–	–	–
1969	7 Jul.	N/A	10 Aug.	N/A	–	–	–	–	–	–	–	–
1970	7 Jul.	N/A	23 Jul.	N/A	–	–	–	–	25 Jul.	N/A	25 Jul.	N/A
1971	10 Jul.	N/A	27 Jul.	N/A	–	–	–	–	24 Jul.	N/A	–	–
1972	13 Jul.	5/Tr	27 Jul.	Tr/Tr	–	–	–	–	26 Jul.	Tr/10	–	–
1973	12 Jul.	Tr/100	3 Aug.	40/100	–	–	–	–	–	–	–	–
1974	23 Jul.	Tr/Tr	8 Aug.	Tr/90	24 Jul.	Tr/Tr	–	–	–	–	–	–
1975	1 Jul.	Tr/20	30 Jul.	Tr/100	26 Jul.	Tr/Tr	–	–	26 Jul.	Tr/Tr	–	–
1976	28 Jun.	10/Tr	21 Jul.	Tr/Tr	22 Jul.	Tr/Tr	–	–	26 Jul.	Tr/Tr	–	–
1977	13 Jul.	2/50	18 Jul.	20/100	26 Jul.	Tr/Tr	3 Aug.	1/10	22 Jul.	Tr/Tr	22 Jul.	Tr/Tr
1978	26 Jul.	Tr/Tr	9 Jul.	Tr/Tr	27 Jul.	2/Tr	27 Jul.	Tr/10	26 Jul.	10/100	28 Jul.	Tr/Tr
1979	11 Jul.	Tr/Tr	19 Jul.	Tr/Tr	–	–	8 Aug.	Tr/Tr	11 Aug.	Tr/Tr	–	–
1980	10 Jul.	Tr/Tr	18 Jul.	Tr/5	–	–	–	–	–	–	–	–
1981	2 Jul.	5/5	8 Jul.	Tr/Tr	–	–	–	–	29 Jul.	Tr/Tr	29 Jul.	Tr/100
1982	16 Jul.	Tr/Tr	16 Jul.	Tr/Tr	–	–	–	–	29 Jul.	Tr/Tr	29 Jul.	Tr/100
1983	6 Jul.	2/100	15 Jul.	Tr/100	31 Jul.	–	–	–	31 Jul.	Tr/Tr	–	–
1984	6 Jul.	Tr/100	–	–	–	–	–	–	–	–	–	–
1985	6 Jul.	2/10	9 Jul.	Tr/Tr	–	–	–	–	–	–	–	–
1986	13 Jun.	Tr/Tr	31 Jul.	10/60	8 Jul.	60/100	–	–	9 Jul.	30/100	–	–
	Ward County				**Foster County**				**Cavalier County**			
1965	12 Jul.	–	–	–	–	–	–	–	15 Jul.	–	11 Aug.	–
1966	23 Jul.	–	–	–	23 Jul.	–	–	–	18 Jul.	–	–	–
1967	10 Jul.	–	–	–	–	–	–	–	27 Jul.	–	22 Aug.	–
1968	27 Jul.	–	–	–	29 Jul.	–	–	–	25 Jul.	–	–	–
1969	26 Jul.	–	16 Aug.	–	26 Jul.	–	–	–	26 Jul.	–	–	–
1970	22 Jun.	–	25 Jul.	–	25 Jul.	–	25 Jul.	–	26 Jul.	–	26 Jul.	–
1971	24 Jul.	–	–	–	25 Jul.	–	25 Jul.	–	26 Jul.	–	26 Jul.	–
1972	26 Jul.	20/Tr	26 Jul.	Tr/Tr	26 Jul.	Tr/100	26 Jul.	Tr/Tr	21 Jul.	Tr/10	9 Aug.	Tr/Tr
1973	24 Jul.	5/80	–	–	25 Jul.	Tr/Tr	3 Aug.	40/100	25 Jul.	Tr/Tr	–	–
1974	25 Jul.	Tr/Tr	1 Aug.	Tr/Tr	21 Jul.	Tr/10	–	–	6 Aug.	Tr/Tr	6 Aug.	Tr/80
1975	6 Jul.	7/10	11 Aug.	Tr/Tr	24 Jul.	Tr/Tr	28 Jul.	Tr/Tr	28 Jul.	10/100	28 Jul.	Tr/Tr
1976	16 Jul.	Tr/100	24 Jul.	Tr/Tr	25 Jul.	60/100	–	–	26 Jul.	40/100	–	–
1977	14 Jul.	20/100	14 Jul.	Tr/Tr	–	–	13 Jul.	Tr/Tr	14 Jul.	Tr/Tr	30 Jul.	Tr/Tr
1978	29 Jul.	5/Tr	29 Jul.	Tr/Tr	30 Jul.	5/40	12 Jul	Tr/Tr	30 Jul.	Tr/Tr	30 Jul.	Tr/Tr
1979	10 Aug.	Tr/Tr	10 Aug.	Tr/Tr	25 Jul.	Tr/Tr	19 Jul.	Tr/Tr	12 Aug.	30/100	12 Aug.	40/100
1980	–	–	–	–	16 Jul.	Tr/Tr	6 Aug.	Tr/Tr	13 Aug.	Tr/Tr	6 Aug.	10/100
1981	29 Jul.	30/100	29 Jul.	2/20	29 Jul.	1/Tr	29 Jul.	10/100	1 Aug.	Tr/Tr	31 Jul.	10/100
1982	10 Aug.	10/Tr	31 Jul.	Tr/100	26 Jul.	Tr/100	26 Jul.	Tr/60	30 Jul.	Tr/20	30 Jul.	Tr/Tr
1983	31 Jul.	30/100	31 Jul.	Tr/Tr	14 Jul.	Tr/Tr	4 Aug.	Tr/100	14 Jul.	Tr/Tr	1 Aug.	Tr/10
1984	1 Aug.	Tr/Tr	13 Jul.	Tr/60	2 Aug.	60/80	2 Aug.	Tr/Tr	2 Aug.	30/70	–	–
1985	6 Aug.	Tr/Tr	23 Jul.	Tr/Tr	6 Aug.	20/100	22 Jul.	Tr/Tr	23 Jul.	Tr/10	23 Jul.	Tr/80
1986	9 Jul.	Tr/Tr	28 Jul.	Tr/80	9 Jul.	20/100	24 Jul.	5/10	30 Jul.	20/100	–	–

[a] Sev/Incid: severity (percentage of tiller infected on modified Cobb scale)/incidence (percentage of plants infected). Tr = fewer than five pustules per tiller, and less than one tiller of 100 infected; N/A = data not available.
[b] No stem rust observed as reported throughout the season.

Dakota. The area planted to winter wheat has gradually expanded to the north and east, and currently, some winter wheat is grown throughout the state, except in the northeast. Table 3 shows the greater favorability for rust development in eastern North Dakota, where wheat stem rust has been observed annually in Cass and Cavalier counties. Stem rust was absent only in 1977 and 1980 in Foster and Ward counties, respectively, whereas it was observed in only 9 and 13 of the 21-yr period in Williams and Golden Valley counties, respectively.

Wheat and oat stem rusts normally occur in the same areas and at about the same severity on susceptible cultivars in the Great Plains. The exceptions are Oklahoma and Kansas, where few oats are grown. In 1986, wheat stem rust was more abundant, particularly in the northern Great Plains (Table 4). Whereas the onset of wheat stem rust was 1–2.5 wk earlier than the long-term average, oat stem rust onset was near the long-term mean at four of the six stations for which long-term records are kept (Table 5).

DISCUSSION

East of the Sierra Madre Oriental mountains of Mexico, wheat is grown during the winter only in the immediate area of the Rio Grande. Rust develops in El Baja Plateau of central Mexico at about the same time as in Texas because of the difference in elevation. The major Mexican wheat-producing area of the Yaqui and Mayo river valleys is at the same latitude as southern Texas and is separated from the Great Plains by a 1,000-km band of mountains and deserts (5). Thus, Mexico is not the annual source of the inoculum that generates wheat stem rust in the Great Plains of the United States.

The abundant wheat stem rust in the southern Great Plains in 1986 is thought to be due to the vast amount of inoculum produced in a small area along the Gulf Coast. Assuming 5,000 uredospores per uredium per day (11) and an average severity of 50% for a 20-day period with 2.5 million tillers per hectare, this area could have produced 1.3×10^{14} uredospores. The more severe wheat stem rust than oat stem rust development in the southern Great Plains probably then resulted from the longer time the disease had to develop because of the early disease onset (Table 5) and the large amount of inoculum from the Gulf Coast. No major change in pathogen virulence was observed in 1986 (9). No major shift in the cultivars grown occurred from 1985 to 1986 in the Great Plains according to our unpublished field observations and state statistical reports. Although the environment has a great effect on epidemic development, the variation in environment across large areas has made it impossible to currently relate individual factors to regional disease development. However, oat stem rust, a very similar disease in its response to environmental conditions, was not unusually severe in the Texas overwintering area (Table 2). No great change occurred in the level of resistance/susceptibility of the cultivars grown in this area from recent years. The wheat stem rust spread northward and was reported in Kansas and Nebraska 10–11 days earlier than the mean of the years of severe regional epidemics (Table 3). In the northern Great Plains, however, the disease appeared 4 days later than the mean of the epidemic years at Brookings and 3–6 days earlier at St. Paul and Fargo.

Thus, in early July, there was little reason to think that an unusual amount of stem rust would be found in the western Dakotas. The observed pattern of old lesions low in the canopy and foci were typical of areas where stem rust overwinters. In areas of spring-planted wheat, the oldest lesions generally occur on the flag or penultimate leaves (6). These infections result from exogenous uredospores being deposited high in the canopy. Earlier arrival of uredospores in the spring wheat region generally fails to result in infection because of the low minimum temperatures. Thus, the inoculum for western North Dakota arrived either in the fall after the winter wheat was planted (September to November) or in the spring before the spring wheat had emerged (early May).

Heavy stem rust infection on winter wheat, with the oldest infection low in the canopy, indicated a very early disease onset. The lack of similar old infections in susceptible spring wheat plots and on wild oats indicates a disease onset before spring plants emerged. Furthermore, the development of foci from the bottom of the plant is generally associated with endogenous inoculum (6). It is impossible to prove in retrospect whether the stem rust on winter wheat overwintered in North Dakota or was a very early spring infection. However, an early spring infection would have also been expected to occur in the eastern Dakotas and Minnesota, where conditions were more favorable for spore transport and infection. The inoculum available for transport at this time would have been in south and/or central Texas, where oat stem rust was also present. This should have resulted in at least occasional infections on the early wild oats; however, these were not observed.

Table 4. Terminal severity and incidence of wheat and oat stem rust at selected counties across the Great Plains in 1986

Location	Wheat stem rust			Oat stem rust		
	Date	Severity[a]	Incidence[a]	Date	Severity	Incidence
Bee, TX	10 Apr.	90	100	10 Apr.	20	100
Bell, TX	21 Apr.	Tr	5	21 Apr.	5	Tr
Collins, TX	13 May	100	100	–[b]	–	–
Uvalde, TX	11 Apr.	Tr	Tr	30 Apr.	20?	100
Jackson, OK	21 May	30	100	–	–	–
Payne, OK	20 May	5	100	–	–	–
Reno, KS	19 May	Tr	Tr	–	–	–
Republic, KS	10 Jun.	60	100	–	–	–
Phillips, KS	11 Jun.	20	100	10 Jun.	Tr	100
Saunders, NE	10 Jun.	5	100	10 Jun.	Tr	Tr
Codington, SD	7 Jul.	74	80	7 Jul.	Tr	50
Spink, SD	24 Jun.	25	100	7 Jul.	Tr	Tr
Dakota, MN	10 Aug.	100	100	17 Jul.	Tr	Tr
Waseca, MN	9 Jul.	2	90	17 Jul.	20	50
Redwood, MN	9 Jul.	2	100	–	–	–
Stephens, MN	28 Jul.	5	100	31 Jul.	2	100
Polk, MN	28 Jul.	20	100	31 Jul.	20	100
Wadena, MN	11 Jul.	Tr	Tr	1 Aug.	40	100
Cass, ND	25 Jul.	40	100	15 Jul.	30	100
Foster, ND	24 Jul.	35	100	24 Jul.	5	100
Cavalier, ND	30 Jul.	20	100	–	–	–
Golden Valley, ND	8 Jul.	60	100	–	–	–
Williams, ND	15 Jul.	35	100	–	–	–
Ward, ND	28 Jul.	40	100	28 Jul.	Tr	80
Richland, MT	28 Jul.	60	100	28 Jul.	Tr	10

[a] Severity = percentage of tiller infected on modified Cobb scale and incidence = percentage of tillers infected. Tr = trace (less than 1 percent), and ? = reported as moderate in area.
[b] Oat stem rust not observed or reported from this location.

Table 5. The deviation in days of the 1986 onset of wheat and oat stem rust at six Great Plains locations from the long-term means[a]

Stem rust	North central Texas	Northeast Kansas	Southeast Nebraska	East central South Dakota	Southeast Minnesota	Southeast North Dakota
Wheat	−11	−17	−12	−8	−8	−15
Oats	0	−8	−16	−1	+2	+2

[a] Mean for wheat stem rust for 65-yr data in part from Hamilton and Stakman (1); mean for oat stem rust for 46-yr data.

Overwintering rust on wild oats in this area is not possible because green plants do not survive the winter. These observations lead us to believe that stem rust overwintered on winter wheat in western North Dakota in 1986, perhaps for the first time in history, although wheat stem rust has overwintered on wheat in Wisconsin (3). Perhaps, the overwintering of wheat stem rust in 1986 was due to the heavy snow that fell in late November and remained as a protective blanket during the winter, but other factors may also be involved. Cultivars currently grown have increased winter-hardiness compared with a few years ago. Deep-furrow planting and fertilization may have also resulted in better plant growth, providing a better host for the rust. Conservation tillage practices increase the chance of snow remaining on the field because of retention of debris. Field survey notes indicate that the most severely infected fields were those where conservation tillage was practiced.

In North Dakota, oat stem rust was not observed in either Beach or Williston and only in low severities at the other locations. Although there is more area planted to wheat than oats in North Dakota, most of the wheat acreage (over 90%) is nearly immune to stem rust while the oats are susceptible to the primary race NA-27 (89% of the isolates identified in the United Staes in 1986 [9]). Additionally, wild oats are susceptible to the entire population of oat stem rust. More wheat stem rust occurred in western North Dakota than expected based on the historical data set, whereas oat stem rust followed the normal pattern. This normal level of oat stem rust indicates that environmental conditions were not uniquely favorable for wheat stem rust development in 1986.

Other hosts exist throughout the United States for wheat stem rust. Most of these hosts appear to be infected only when the wheat in the vicinity is infected. *Hordeum pusillum* Nutt. and *Aegilops cylindrica* Host. in the southern Great Plains and *H. jubatum* L. in the northern Great Plains are typical hosts of this type, as is cultivated barley (*H. vulgare* L.). These hosts exist during the wheat-growing period and are often dormant during the summer. Thus, they have little role in the spread or increase of the pathogen, except for *H. jubatum*, which may serve as a green bridge in the summer in the north central Great Plains. In contrast, an introduced perennial bunch grass, Russian wild rye (*Elymus junceus* Fisch.), is being proposed for use in North Dakota. Rust collections from Russian wild rye in 1984 and 1986 were identified as wheat stem rust. Wild rye appears to have been an overwintering host for stem rust in western North Dakota in both 1984 and 1986. In 1984, heavily infected foci were found in Russian wild rye when no rust was observed on susceptible wheat cultivars nearby. In 1986, both the wild rye and susceptible winter wheats were severely infected. Winter wheat in this area is usually winter-killed to the crown, leaving no green tissue on which rust may survive. Thus, the appearance of severe stem rust in the northern Great Plains may become more common if an effective overwintering host is widely introduced.

LITERATURE CITED

1. Hamilton, L. M., and Stakman, E. C. 1967. Time of stem rust appearance on wheat in the western Mississippi basin in relation to the development of epidemics from 1921 to 1962. Phytopathology 57:609-613.
2. Hassan, Z. M., Kramer, C. L., and Eversmeyer, M. G. 1986. Summer and winter survival of *Puccinia recondita* and infection by soilborne urediniospores. Trans. Br. Mycol. Soc. 86:365-372.
3. Paxson, G. E. 1921. Observation on the overwintering of black stem rust of wheat in the vicinity of Madison, Wisconsin. M.S. thesis. University of Wisconsin, Madison. 49 pp.
4. Roelfs, A. P. 1978. Estimated losses caused by rust in small grain cereals in the United States—1918-76. U.S. Dep. Agric. Misc. Publ. 1363. 85 pp.
5. Roelfs, A. P. 1982. Effects of barberry eradication on stem rust in the United States. Plant Dis. 66:177-188.
6. Roelfs, A. P. 1985. Epidemiology in North America. Pages 403-434 in: The Cereal Rusts. Vol 2. Diseases, Distribution, Epidemiology, and Control. A. P. Roelfs and W. R. Bushnell, eds. Academic Press, Orlando.
7. Roelfs, A. P. 1986. Development and impact of regional cereal rusts epidemics. Pages 129-150 in: Plant Disease Epidemiology. Vol. 1. Population Dynamics and Management. K. J. Leonard and W. E. Fry, eds. Macmillan, New York.
8. Roelfs, A. P. 1986. Monitoring stem rust epidemics in the Great Plains. Pages 527-532 in: The Movement and Dispersal of Agriculturally Important Biotic Agents. D. R. Mackenzie, C. S. Barfield, G. G. Kennedy, and R. D. Berger with D. J. Taranto, eds. Claitors Publishing, Baton Rouge.
9. Roelfs, A. P., Casper, D. H., Long, D. L., and Roberts, J. J. 1987. Races of *Puccinia graminis* in the United States and Mexico during 1986. Plant Dis. 71:903-907.
10. Roelfs, A. P., and Long, D. L. 1980. Analysis of recent oat stem rust epidemics. Phytopathology 70:436-440.
11. Rowell, J. B., and Roelfs, A. P. 1971. Evidence for an unrecognized source of overwintering wheat stem rust in the United States. Plant Dis. Rep. 55:990-992.