MINNESOTA

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Wheat Rusts in the United States in 2004.

Wheat stem rust (***Puccinia graminis f. sp. tritici***). The first reports of wheat stem rust in 2004 were in late April, when trace levels of infection were found in plots at Giddings in central Texas and at Quincy in the Florida panhandle. The next report of wheat stem rust was in early June, when trace to 5% severities were reported in a wheat breeding nursery in northeastern Kansas. In early June, traces of wheat stem rust were found in an experimental line in a nursery in northeastern Missouri.

In late June, severe stem rust was observed in plots of the susceptible cultivar RedChief at Lincoln Nebraska. In late June, traces of stem rust were found in a field of triticale in southeastern Minnesota, which is in the same area where barberry bushes occur. The stem rust found on triticale was determined to be rye stem rust.

In the first week of July, trace levels of stem rust infections were found on the susceptible spring wheat Baart in southern Minnesota. By mid-July, 20-60% severities were observed on Baart in central Minnesota and central South Dakota plots. All of the current spring wheat cultivars are resistant to the current race population. In susceptible winter wheat plots in east central Minnesota, trace to 60% severities were found at the soft dough growth stage. In mid-July, traces of wheat stem rust were found on winter wheat in west central Wisconsin. In late July, trace to 20% severities were observed on the susceptible spring wheat Baart in central North Dakota and north central Minnesota.

From April to June, there were very few reports of wheat stem rust being found in the southern and central plains. However, in July stem rust was present on susceptible cultivars at many locations from western Wisconsin to central North Dakota. Therefore, the stem rust that developed throughout the north must have originated from the few inoculum sources in the southern and central plains.

Race QFCS, the predominant race found in the Great Plains the past few years, was again the predominant race identified in 2004 (Table 1). The majority of wheat varieties in the United States are resistant to race QFCS. Races MCC and TPMK were found at localities where field inoculation was used in the screening nurseries. Race QCCN, a race similar to QCCJ in virulence, was identified from a collection from Washington.

Wheat Leaf Rust (***Puccinia triticina***). **Southern Plains** - In late January, traces of leaf rust were found in central Texas plots. Cool temperatures during early February slowed leaf rust development. By late February, 40% leaf rust severities were observed in central Texas plots. In the second week of March, 60% leaf rust severities were reported on susceptible cultivars in southern Texas (east of San Antonio). Leaf rust was scattered and severe in more places throughout Texas than in 2003.

By early March, leaf rust was present in Oklahoma but at lower severity levels than in the previous fall. In 2004, cold temperatures during mid-January to mid-February were not conducive for over wintering of rust in Oklahoma.

In late March, in southern and central Texas, leaf rust infections were at low severity levels in most commercial wheat fields (Fig. 1) and at high severity levels on susceptible cultivars in nursery plots. Leaf rust severities up to 80% were found on lower leaves of cultivars in nurseries, and trace-20% severity levels were on lower leaves in fields. Rainfall in mid to late March contributed to the leaf rust development in the southern Great Plains.

In mid-April, leaf rust was found from Texas to Kansas. In most of southern and central Texas, rain and dew periods were ideal for the infection process to occur. In a central Texas nursery on the susceptible cultivar Jagger, the leaves were completely dead due to heavy rust infections.

In late April in central Texas, susceptible cultivars had moderate to high severities of rust infection, while in northern Texas susceptible cultivars had light to moderate leaf rust infection. In central Texas fields, 40% severities were observed in fields that had been sprayed with fungicide (Fig. 1). By early May, leaf rust was increasing throughout Oklahoma, but drier than normal conditions in mid-May significantly slowed rust development. As in previous years, Jagger wheat was heavily rusted and some yield reduction occurred. Leaf rust in the southern Great Plains was more severe than 2003, but dry conditions in some areas slowed rust development.

Central Plains – In early April, traces of leaf rust were found in several fields in south central Kansas. In early May, leaf rust was present in most of Kansas at trace severities except in south central Kansas where 10% severities were reported on lower leaves in some fields. By the third week in May, leaf rust was starting to increase on flag leaves in south central Kansas.

In the last week in May, leaf rust was severe in plots and fields of susceptible cultivars from north central Kansas to west central Missouri (Fig 1). At the late berry stage in south central Kansas, Jagger had 60% rust severities on flag leaves while in northeast Kansas, Jagger had 20% rust severities. In central Kansas varietal plots, rust severities ranged from trace to 80%. In southern Kansas, losses due to leaf rust were severe in Jagger, while other leaf rust susceptible cultivars had lower yield losses (Table 4). Rainfall in late May, in Kansas and Nebraska allowed leaf rust to increase which provided inoculum for the northern wheat growing area.

In mid June, leaf rust was severe in southeast and south central Nebraska (Fig. 1). Rust severities on flag leaves were 60 to 80% in fields and experimental plots. Abundant rainfall in eastern and southern Nebraska provided good moisture conditions for rapid increase of leaf rust infections. In western Nebraska where it was much dryer, only trace levels of leaf rust infections were observed (Table 4).

Northern Plains – In early June, trace amounts of leaf rust were found on winter wheat lines in plots at Brookings in east central South Dakota.

In early June, trace levels of leaf rust were found in winter wheat plots in east central Minnesota. Traces of leaf rust infections were also found in spring wheat in the Red River Valley in early June. In mid-June, leaf rust was increasing in winter wheat in southeastern South Dakota and southern Minnesota, with severities of 20-40% on lower leaves and 10-20% on flag leaves. The spring wheat crop had trace to 5% levels of infections on lower leaves. In mid-June in an east central South Dakota rust nursery, high levels of leaf rust were observed on the susceptible spring wheat varieties Thatcher, Baart and Morocco. During the second week in June, traces of leaf rust were found in fields in southeast and north central North

Dakota. Rainfall and cool-warm temperatures provided suitable conditions for the increase and spread of leaf rust in the north central region.

In early July in east central Minnesota plots, susceptible winter wheat cultivars such as Jagger had 80% rust severities, but the resistant cultivars had only trace levels of infections on the flag leaves. The leaf rust did not over winter in the Minnesota plots, but probably originated from field infections in Oklahoma and Kansas.

In early July, susceptible spring wheat cultivars in southern Minnesota plots had 20% rust severities, with most infections on the lower leaves. Trace levels of leaf rust were observed in many of the spring wheat fields in southern Minnesota (Fig. 1). In the first week of July, leaf rust severities were up to 80% on susceptible spring wheat cultivars such as Ingot in southern and west central Minnesota varietal plots. The spring wheat Oxen, which is commonly grown in southern Minnesota, had leaf rust severities of 30-60%; the cultivar Alsen had leaf rust severities of 5-10% in southern and west central Minnesota.

In mid-July, 10-40% leaf rust severities were observed on flag leaves of spring wheat cultivars in fields from northwestern South Dakota to northeastern Wisconsin.

In late July, spring wheat varietal plots had trace to 60% leaf rust severities in central and eastern North Dakota. Fields in southeastern and central North Dakota of commonly grown wheat cultivars had severity levels of 20%. Many wheat fields were sprayed with fungicide to prevent losses due to rust and scab. In the northern tier of counties in North Dakota leaf rust was at reduced levels because the crop maturity was later than normal.

This year leaf rust was severe and concentrated in the upper Midwest. Rust inoculum arrived from the south in late May and early June with rain showers while temperature and moisture conditions were good for infection and spread of leaf rust. The spring wheat cultivars currently grown have less effective resistance to leaf rust than those that were popular 10-15 years ago. Losses to wheat leaf rust occurred in cultivars that had not been sprayed with fungicide. In 2004, a 10% loss in the spring wheats to leaf rust was determined in Minnesota (Table 4).

Southeast - In mid-January, leaf rust was reported in southwest Louisiana. By early March, leaf rust was at significant severity levels in south/west central Louisiana. Rust was widespread and severities of 30% were in nursery plots and fields. Some cultivars had heavy rust severities on older leaves (fall infection), but low severities on the upper leaves.

In mid-February, fields and plots in Baldwin County in southwest Alabama had low severities of leaf rust. In late February weather conditions were ideal for further rust development in the southeastern U.S.

In late March, leaf rust was present in fields and plots in the southern soft red winter wheat area from Georgia to Arkansas. Some of the fields infected with rust were sprayed for rust control.

In mid-April from central Louisiana through Alabama to Georgia, low levels of leaf rust infection were observed in research plots and fields. On a few susceptible cultivars 40% severities were reported in south central Louisiana nurseries. In early May, plots from central Texas to the Florida Panhandle had 80% leaf rust severities.

By mid-April, leaf rust was increasing in areas of Arkansas that had sufficient moisture. In late April, light to moderate leaf rust was in Arkansas fields and plots. In early May nursery plots in northwestern Arkansas had 50% rust severities. In mid-May, leaf rust was prevalent throughout Arkansas, but rust infections developed later than normal and did not cause much yield loss (Table 4).

Mideast - In late May, susceptible cultivars had 20-25% leaf rust severities at the late milk stage in southwest Indiana wheat plots. This was the most leaf rust seen in a number of years in this area. In early June, plots in west central Indiana had 20% severities while traces were found in fields.

In early June, leaf rust developed late in central Ohio and susceptible cultivars had 20% severities on flag leaves, which resulted in losses. During the second week in June, trace to 10% severities was found in plots in northwest Ohio, northern Indiana and south central Wisconsin. Only light losses occurred in this area (Table 4).

East – In late May, hot, dry weather hastened the maturity of small grains in the Carolinas and Virginia. Powdery mildew was widespread on wheat and in some fields appeared to be at damaging levels. Leaf rust on winter wheat was either non-existent or very light in commercial fields. In nursery plots in eastern North Carolina, leaf rust was severe only on fully susceptible cultivars.

In eastern Virginia, the wheat crop matured 10 days earlier than normal because of the hot temperatures in May, which halted the leaf rust development. In early June in western Virginia, the crop matured at a normal pace and more leaf rust was found there. Varieties with *Lr26*, e.g. USG 3209 and Sisson, had considerable leaf rust. In early June, moderate to light levels of leaf rust infection were observed in winter wheat plots in central Maryland.

In early July, wheat leaf rust was widespread, but not severe throughout western/central New York.

California - Wheat leaf rust was late to develop and was only found on a few cultivars. The wheat crop matured early and leaf rust did not affect the yield.

Pacific Northwest - In late May, trace amounts of leaf rust were observed in wheat plots and fields in northwest Washington. In early June, severe leaf rust was reported in the Willamette Valley in northwest Oregon.

In late June, foci of 20% leaf rust severity were found in soft white winter wheat plots in northeastern Oregon at Pendleton. Leaf rust development was light in the Pacific Northwest this year.

Canada - In mid-June, traces levels of leaf rust were found in winter wheat plots south of Winnipeg, Manitoba, Canada.

Wheat Leaf Rust Virulence.
The 2004 leaf rust race identifications are presented in Table 2 and 3 (see Fig. 3 for agroecological area map). A total of 50 leaf rust races were found in the U.S. From the central and southern Plains the most common races were M--- (virulent to *Lr1,3,10,17*) (Table 3). Many of the MBDS and MCDS races were identified from collections made from Jagger, which is widely grown in the southern and central Plains states. There has been an increase in number of T-races (TNRJ and TNBJ) with virulence to *Lr9, 10, 24* in collections made from the cultivars Lockett (*Lr9* resistance) and Thunderbolt (*Lr41* resistance). In 2004, the most common races identified in the northern wheat growing area were T-races (TBBJ, TBDS and TCDS). At the same time there was an increase in the number of K-races (virulent to *Lr2a, 2c and 3* (Table 2). In the soft red wheat area the most common race was MCRK

(virulent to *Lr1,3,3ka,10,11,14a,18,26, 30*). Some of the commonly grown cultivars in this area have *Lr11 and 26* resistance.

Wheat stripe rust (*Puccinia striiformis* f. sp. *tritici*). Southern Plains – In late February, severe wheat stripe rust was found in plots southwest of Houston, Texas. By the second week in March, the stripe rust development in these plots had stopped. In mid-March, there were reports of stripe rust in fields west of Brazos and Williamson counties in central Texas.

In late March, wheat stripe rust infections were at low levels in fields in southern and central Texas (Fig 2). Stripe rust severities ranged from trace levels to 20% in plots and fields. Although rainfall in late March provided high moisture conditions, warmer day and night temperatures restricted stripe rust development. In mid-April, stripe rust was light in southern and central Texas.

In late April, stripe rust was light to moderate in north central Texas and southern Oklahoma plots and fields (Fig. 2). In north central Texas, 60% severities were observed on susceptible varieties. Some fields in this area had been sprayed for rust and mildew control. In early May, stripe rust was found across northern Oklahoma. Rust was present in significant amounts, but dry and windy conditions impeded the further development of stripe rust on susceptible varieties. Hot spots of rust development were found in central and southwestern Oklahoma, but not at levels that caused significant yield losses (Table 4).

This year stripe rust was found in fewer locations and the weather conditions were not as conducive for stripe rust development as 2003 in Texas and Oklahoma. Another possibility is that stripe rust over wintering was reduced compared to previous years. Stripe rust infections in the southern U.S. were less severe and extensive than 2003 and provided less inoculum for the northern wheat growing area.

Central Plains - In mid-May, stripe rust was at trace levels on flag leaves in a central Kansas field. In late May, stripe rust was at trace–10% severity on flag leaves in southeast and south central Kansas fields. Stripe rust was much lighter than last year in this area. In 2003 there was 10.6% loss to stripe rust in Kansas, while in 2004 there was 0.1% loss (http://www.cdl.umn.edu/loss/loss.html).

In late May, low levels of wheat stripe rust were found on flag leaves in north central Kansas (Fig 2). The warm and dry conditions in May reduced further development of stripe rust in Kansas.

In mid-June, stripe rust was not observed in fields or plots in Nebraska, possibly due to the heavy leaf rust infections.

Northern Plains – In early June, stripe rust was found in winter wheat plots in east central South Dakota.

In mid-June, trace levels of stripe rust were in winter wheat fields in south central South Dakota, and in fields of spring and winter wheat in eastern South Dakota (Fig. 2). In winter wheat plots at Brookings, most lines had trace levels of stripe rust infection, however a few plots had very high levels of infection on flag and lower leaves. By the third week in June, trace levels of stripe rust were on spring wheat in St. Paul, Minnesota plots.

In 2003, in early June, traces of stripe rust were found in winter wheat plots in east central Minnesota, but in 2004 stripe rust infections were not found until mid-June at this location.

In early July, stripe rust severity levels of 60% were present in west central

Minnesota spring wheat fields and plots (Fig. 2). The cultivars Trooper and Walworth were the most susceptible with stripe rust infections over 50%. Most of the commonly grown spring wheats have moderate to high resistance to stripe rust. The very cool temperatures with sufficient moisture levels were conducive for stripe rust development in the north central region.

In mid-July, hot temperatures arrested development of stripe rust on spring wheat in the northern Great Plains. In late July, a spring wheat field in north central Minnesota had 5% severity where nighttime temperatures had been more conducive for rust infection.

Louisiana, Arkansas and Missouri – In late February, low levels of stripe rust infections were in southern and east central Louisiana fields. By early April, rust had increased and these fields were sprayed for rust control. By mid-April in northeast Louisiana, stripe rust was severe in soft red winter wheat varietal plots. Some fields were sprayed to reduce losses due to rust. Significant amounts of stripe rust have occurred in five of the last seven years in Louisiana.

In late March, wheat stripe rust was found in fields throughout southeast Arkansas and fungicide application was recommended. In mid-April in southwest Arkansas wheat plots, little stripe rust was found on the most commonly grown varieties. In late April, stripe rust was at trace levels in eastern and northern Arkansas. By early May, in northern Arkansas, some cultivars had 100% stripe rust severities. In mid-May, stripe rust development had ceased in Arkansas because the high temperatures at night were not conducive for stripe rust increase.

In late May, 5-10% stripe rust severities were observed in soft red winter wheat fields in west central Missouri. Stripe rust severity was less than last year in this area and the crop was 7-10 days earlier than normal. Traces of stripe rust were observed in plots and fields in northeastern Missouri in early June.

Mideast - In early May, stripe rust was light in wheat fields in southwestern Illinois. Traces of stripe rust were in west central Indiana plots in early June.

During the second week in June, stripe rust foci of 10% severity were located in winter wheat plots and fields in northern Indiana and south central Wisconsin.

During the second week in June, traces of stripe rust were found in plots in central, northeast and northwest Ohio.

In early July, 20% severities were observed in fields of soft red winter wheat in northeastern Wisconsin.

California – Stripe rust on wheat was first detected on February 12 in the UC Regional Wheat Nursery in the Sacramento/San Joaquin Delta nursery in California. Rust was scattered throughout the nursery in light amounts (less than 1% incidence), but pustules on infected plants were sporulating profusely. Infected leaves had up to 30% severity. By early March, wheat stripe rust had increased to 50% severity and 20% incidence in the nursery at Sacramento/San Joaquin Delta. The crop was in late jointing stage. In early March, low levels of wheat stripe rust were found in nurseries in Madera county and Davis, California.

In Mexico, wheat stripe rust in the southern Sonora state was not as severe as in previous years. However, northern Sonora and the neighboring state of Baja California had more rainfall. This area (Mexicali Valley) is close to a U.S. wheat growing area where stripe rust could have an economic impact.

In mid-April, wheat stripe rust was severe in susceptible varieties in nurseries in the Central Valley and Sacramento Valley of California. In the same area stripe rust was at low to moderate severities on durum varieties. Stripe rust infection foci were observed in fields in the Sacramento Valley.

In mid-July, spring wheat plots had 40% stripe rust severities spring wheat plots at the early dough growth stage in northeastern California at Tulelake. Stripe rust foci also were detected in plots of wheat at 90% severity, and 30% incidence in a north central California nursery.

In California, yield losses from stripe rust were considerably less than in 2003 because of the wide-use of resistant varieties and the late development of heavy rust infections (Table 4). One concern in 2004 was that new rust races have developed that are virulent to the resistance that was effective in 2003 and much of the 2004 season. These races may survive in the stripe rust population and appear in higher frequency next season.

Pacific Northwest – In early March, severity levels of 30% were in winter wheat fields and plots in northwestern Washington. Stripe rust was uniformly distributed in commercial fields. Stripe rust severity and distribution patterns were typical for this area. In late March stripe rust was not found on the eastern side of the Rocky Mountains in Washington.

During the last week of April, stripe rust was starting to increase in experimental plots in northeast Oregon and southeast Washington. Near Connell, Washington, severity levels of 20% were in fields planted with 'Hatton', a hard red winter wheat. In 2004, the appearance of stripe rust was much later than 2003, due to the dry weather in the fall of 2003 that reduced fall infection and a cold winter that reduced winter survival. The stripe rust infections were on the top leaves, indicating infections occurred mostly after the winter season. The rust infected winter wheat produced rust spores that infected spring wheat crops in central and eastern Washington and northern Idaho.

By late May, wheat stripe rust was observed on susceptible spring and winter wheat cultivars growing in fields and plots in central and eastern Washington and northern Idaho.

In late June, wheat stripe rust was developing very rapidly in fields of susceptible winter and spring wheat cultivars in eastern Washington. Many of these cultivars have high temperature adult plant resistance, which reduced rust losses. Some fields had incidence levels of 60% stripe rust and severity levels of 20%. Fungicides were applied on susceptible wheat fields. Plots of susceptible lines had 80% severities near Pullman, Washington. In 2004, yield losses to stripe rust occurred in the Pacific Northwest, but were less than 2003 (http://www.cdl.umn.edu/loss/loss.html).

Table 1. Races of *Puccinia graminis* f. sp. *tritici* identified from wheat in 2004.

Area	State	Number of collections	Number of isolates	Number of isolates of Pgt- race[1] QFCS	MCCF	MCCD	TPMK	QCCN
Great Plains	TX	1	1	1				
	OK	1	1	1				
	KS	3	3	3				
	NE	3	2	1			1	
	SD	3	3	3				
	ND	7	6	6				
Midwest	MO	1	1	1				
	IN	1	1		1			
	MN	15	19	15	2	2		
Pacific NW	WA	1	2					2
U.S. Total		36	39	31	3	2	1	2

[1] Pgt race code, after Roelfs and Martens, Phytopathology 78:526-533. Race QFCS virulent to *Sr5, 8a, 9a, 9d, 9g, 10, 17, 21*; MCCF virulent to *Sr5, 7d, 9g, 10, 17, Tmp*; MCCD virulent to *5, 7d, 9g, 10, 17*; TPMK virulent to *Sr5, 7b, 8a, 9d, 9e, 9g, 10, 11, 17, 21, 36, Tmp*; and QCCN virulent to *Sr5, 9a, 9g, 10, 17, 21*.

[2] Set four consists of *Sr9a, 9d, 10* and *Tmp*.

Table 2. Races of Puccinia triticina (wheat leaf rust) in the U.S. in 2004 determined by virulence to 16 near-isogenic lines of Thatcher wheat with leaf rust resistance genes.

Race	Virulence combination1 (ineffective Lr genes)	Area 1[2] #	Area 1 %	Area 2 #	Area 2 %	Area 3 #	Area 3 %	Area 4 #	Area 4 %	Area 5 #	Area 5 %	Area 6 #	Area 6 %	Area 7 #	Area 7 %	Area 8 #	Area 8 %	U.S. Total #	U.S. Total %
BBBD	14a	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	2	0.3
BBBG	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	17	2	0.3
CBBG	3,10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1
CLDS	3,9,17,B,10,14a	0	0	0	0	0	0	2	1	1	1	0	0	0	0	0	0	3	0.4
KBBG	2a,2c,3,10	0	0	0	0	1	2	6	3	5	3	63	26	0	0	1	8	76	10.0
KBBJ	2a,2c,3,10,14a	0	0	0	0	0	0	4	2	4	2	9	4	0	0	0	0	17	2.2
KCBJ	2a,2c,3,26,10,14a	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	2	0.3
KDBG	2a,2c,3,24,10	0	0	0	0	0	0	8	5	4	2	2	1	0	0	0	0	14	1.8
KDBJ	2a,2c,3,24,10,14a	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	4	0.5
KDDG	2a,2c,3,24,17,10	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	4	0.5
KDDJ	2a,2c,3,24,17,10,14a	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	4	0.5
KFBJ	2a,2c,3,24,26,10,14a	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	3	0.4
KGBG	2a,2c,3,16,10	0	0	0	0	1	2	0	0	2	1	11	5	0	0	0	0	14	1.8
KGBJ	2a,2c,3,16,10,14a	0	0	0	0	0	0	0	0	3	1	8	3	0	0	0	0	11	1.4
KJBJ	2a,2c,3,16,24,10,14a	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0.1
MBDS	1,3,17,B,10,14a	7	7	1	7	5	12	32	18	16	9	15	6	0	0	3	25	79	10.4
MBGJ	1,3,11,10,14a	2	2	0	0	4	10	0	0	0	0	0	0	0	0	0	0	6	0.8
MBRJ	1,3,3ka,11,30,10,14a	0	0	0	0	0	0	0	0	1	1	1	*[3]	0	0	0	0	2	0.3
MBRK	1,3,3ka,11,30,10,14a,18	2	2	0	0	1	2	2	1	0	0	0	0	0	0	0	0	5	0.7
MCDS	1,3,26,17,B,10,14a	3	3	4	29	21	50	16	9	21	12	32	13	2	67	3	25	102	13.4
MCRK	1,3,26,3ka,11,30,10,14a,18	29	29	3	21	2	5	0	0	2	1	0	0	0	0	0	0	36	4.7
MDBJ	1,3,24,10,14a	1	1	0	0	0	0	5	3	2	1	2	1	0	0	0	0	10	1.3
MDDS	1,3,24,17,B,10,14a	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	2	0.3
MFBJ	1,3,24,26,10,14a	0	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	2	0.3
MFDS	1,3,24,26,17,B,10,14a	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.3
MHDS	1,3,16,26,17,B,10,14a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	1	0.1
MLDS	1,3,9,17,B,10,14a	0	0	0	0	0	0	13	7	3	2	2	1	0	0	0	0	18	2.4
SBDD	1,2a,2c,17,14a	0	0	0	0	0	0	0	0	0	0	1	*	0	0	0	0	1	0.1
TBBF	1,2a,2c,3,14a,18	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0.1
TBBG	1,2a,2c,3,10	0	0	0	0	0	0	2	1	0	0	2	1	0	0	2	17	6	0.8
TBBJ	1,2a,2c,3,10,14a	8	8	0	0	0	0	16	9	15	9	7	3	0	0	0	0	46	6.0
TBDS	1,2a,2c,3,17,B,10,14a	2	2	0	0	0	0	5	3	21	12	17	7	0	0	0	0	45	5.9
TBRJ	1,2a,2c,3,3ka,11,30,10,14a	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	3	0.4
TBTJ	1,2a,2c,3,3ka,11,17,30,10,14a	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	0.3
TCBJ	1,2a,2c,3,26,10,14a	0	0	2	14	0	0	0	0	10	6	0	0	0	0	0	0	12	1.6
TCDS	1,2a,2c,3,26,17,B,10,14a	4	4	4	29	2	5	0	0	28	16	13	5	0	0	0	0	51	6.7
TCGJ	1,2a,2c,3,26,11,10,14a	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0.9
TCRK	1,2a,2c,3,26,3ka,11,30,10,14a,18	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.5
TCTB	1,2a,2c,3,26,3ka,11,17,30	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.3
TCTD	1,2a,2c,3,26,3ka,11,17,30,14a	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.5
TCTG	1,2a,2c,3,26,3ka,11,17,30,10	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.4
TDBJ	1,2a,2c,3,24,10,14a	0	0	0	0	0	0	6	3	1	1	0	0	0	0	0	0	7	0.9
TDDS	1,2a,2c,3,24,17,B,10,14a	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0.1
TGBJ	1,2a,2c,3,16,10,14a	1	1	0	0	0	0	0	0	0	0	5	2	0	0	0	0	6	0.8
THBJ	1,2a,2c,3,16,26,10,14a	2	2	0	0	0	0	8	5	3	2	17	7	0	0	0	0	30	3.9
TJBJ	1,2a,2c,3,16,24,10,14a	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	0.3
TLGJ	1,2a,2c,3,9,11,10,14a	10	10	0	0	1	2	6	3	0	0	2	1	0	0	0	0	19	2.5
TLRJ	1,2a,2c,3,9,3ka,11,30,10,14a	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	2	0.3

TNBJ 1,2a,2c,3,9,24,10,14a	2	2	0	0	0	0	0	0	4	2	2	1	1	33	0	0	9	1.2
TNRJ 1,2a,2c,3,9,24,3ka,11,30,10,14a	5	5	0	0	0	0	32	18	13	8	27	11	0	0	0	0	77	10.1
Total	101		14		42		177		172		242		3		12		763	

[1] Differentials used: 1,2a,2c,3,9,16,24,26,3ka,11,17,30,B,10,14a,18

[2] See Fig. 3.

[3] Less than 0.6%

Table 3. Virulence frequencies (%) of Puccinia triticina in the U.S. in 2004 to 16 differential lines of Thatcher wheat with leaf rust resistance genes.

Resistance gene	Area 1[1] #	Area 1[1] %	Area 2 #	Area 2 %	Area 3 #	Area 3 %	Area 4 #	Area 4 %	Area 5 #	Area 5 %	Area 6 #	Area 6 %	Area 7 #	Area 7 %	Area 8 #	Area 8 %	U.S. Total #	U.S. Total %
Lr1	100	99.0	14	100.0	39	92.9	149	84.2	142	82.6	149	61.6	3	100.0	9	75.0	605	79.3
Lr2a	54	53.5	6	42.9	7	16.7	107	60.5	122	70.9	190	78.5	1	33.3	3	25.0	490	64.2
Lr2c	54	53.5	6	42.9	7	16.7	107	60.5	122	70.9	190	78.5	1	33.3	3	25.0	490	64.2
Lr3	101	100.0	14	100.0	42	100.0	177	100.0	170	98.8	241	99.6	3	100.0	10	83.3	758	99.3
Lr9	17	16.8	0	0	1	2.4	55	31.1	21	12.2	33	13.6	1	33.3	0	0	128	16.8
Lr16	3	3.0	0	0	2	4.8	8	4.5	8	4.7	43	17.8	0	0	1	8.3	65	8.5
Lr24	10	9.9	0	0	3	7.1	60	33.9	33	19.2	35	14.5	1	33.3	0	0	142	18.6
Lr26	60	59.4	13	92.9	27	64.3	24	13.6	69	40.1	62	25.6	2	66.7	4	33.3	261	34.2
Lr3ka	49	48.5	3	21.4	3	7.1	39	22.0	16	9.3	30	12.4	0	0	0	0	140	18.3
Lr11	68	67.3	3	21.4	8	19.0	45	25.4	16	9.3	32	13.2	0	0	0	0	172	22.5
Lr17	27	26.7	9	64.3	28	66.7	77	43.5	92	53.5	82	33.9	2	66.7	7	58.3	324	42.5
Lr30	49	48.5	3	21.4	3	7.1	39	22.0	16	9.3	30	12.4	0	0	0	0	140	18.3
LrB	18	17.8	9	64.3	28	66.7	69	39.0	92	53.5	79	32.6	2	66.7	7	58.3	304	39.8
Lr10	95	94.1	14	100.0	41	97.6	177	100.0	170	98.8	241	99.6	3	100.0	12	100.0	753	98.7
Lr14a	95	94.1	14	100.0	40	95.2	157	88.7	161	93.6	164	67.8	3	100.0	7	58.3	641	84.0
Lr18	35	34.7	3	21.4	4	9.5	2	1.1	2	1.2	0	0	0	0	0	0	46	6.0
Total	101		14		42		177		172		242		3		12		763	

[1] See Fig. 3.

Table 4. Estimated losses in winter wheat due to rust in 2004.

				Losses due to					
				Stem rust		Leaf rust		Stripe rust	
State	1000 acres harvested	Yield in bushels per acre	Production in 1000 of bushels	%	1000 bushels	%	1000 bushels	%	1000 bushels
AL	60	48.0	2,880	0.0	0.0	1.0	29.1	*T	T
AR	620	53.0	32,860	0.0	0.0	T	T	**2.0**	670.6
CA	320	85.0	27,200	0.0	0.0	T	T	**5.0**	1,431.6
CO	1,700	27.0	45,900	0.0	0.0	T	T	T	T
DE	47	58.0	2,726	0.0	0.0	T	T	0.0	0.0
FL	15	45.0	675	0.0	0.0	1.0	6.8	T	T
GA	190	45.0	8,550	0.0	0.0	1.0	86.4	0.0	0.0
ID	700	90.0	63,000	0.0	0.0	T	T	T	T
IL	900	59.0	53,100	0.0	0.0	1.0	536.4	T	T
IN	440	62.0	27,280	0.0	0.0	1.0	275.6	T	T
IA	24	55.0	1,320	0.0	0.0	T	T	T	T
KS	8,500	37.0	314,500	0.0	0.0	**1.4**	4,470.1	0.1	319.2
KY	380	54.0	20,520	0.0	0.0	T	T	T	T
LA	165	50.0	8,250	0.0	0.0	**1.5**	131.6	**4.5**	394.9
MD	145	59.0	8,555	0.0	0.0	T	T	0.0	0.0
MI	640	64.0	40,960	0.0	0.0	1.0	413.7	T	T
MN	25	40.0	1,000	0.0	0.0	1.0	10.1	T	T
MS	135	53.0	7,155	0.0	0.0	1.0	73.8	**2.0**	147.5
MO	930	52.0	48,360	0.0	0.0	1.0	488.5	T	T
MT	1,630	41.0	66,830	0.0	0.0	T	T	1.0	675.1
NE	1,650	37.0	61,050	0.0	0.0	**3.0**	1,888.1	T	T
NJ	24	47.0	1,128	0.0	0.0	T	T	0.0	0.0
NM	300	26.0	7,800	0.0	0.0	0.0	0.0	0.0	0.0
NY	100	53.0	53,300	0.0	0.0	T	T	0.0	0.0
NC	460	50.0	23,000	0.0	0.0	T	T	0.0	0.0
ND	225	44.0	9,900	0.0	0.0	1.0	100.0	T	T
OH	890	62.0	55,180	0.0	0.0	1.0	557.4	T	T
OK	4,700	35.0	164,500	0.0	0.0	**1.5**	2,517.9	0.5	839.3
OR	780	61.0	47,580	0.0	0.0	0.2	98.3	**3.0**	1,474.6
PA	135	49.0	6,615	0.0	0.0	T	T	0.0	0.0
SC	180	44.0	7,920	0.0	0.0	0.5	15.9	0.0	0.0
SD	1,250	45.0	56,250	0.0	0.0	1.0	568.2	568.2	T T
TN	280	49.0	13,720	0.0	0.0	T	T	T	T
TX	3,500	31.0	108,500	0.0	0.0	**4.7**	5,477.4	**2.2**	2,563.9
UT	120	43.0	5,160	0.0	0.0	0.0	0.0	0.0	0.0
VA	180	55.0	9,900	0.0	0.0	0.1	9.9	0.0	0.0
WA	1,750	67.0	117,250	0.0	0.0	T	T	**1.5**	1,785.5
WV	5	52.0	260	0.0	0.0	T	T	0.0	0.0
WI	225	56.0	12,600	0.0	0.0	1.0	131.2	T	T
WY	135	26.0	3,510	0.0	0.0	0.0	0.0	0.0	0.0
Total from Above	34,455	43.5	1,498,744		0.0		17,886.4		10,302.2
U.S.%Loss				0.00		1.02		0.67	
U.S. Total	34,462	43.5	1,499,434						

*T=Trace

Table 5. Estimated losses in spring and durum wheat due to rust in 2004.

SPRING WHEAT

State	1000 acres harvested	Yield in bushels per acre	Production in 1000 of bushels	Losses due to: Stem rust %	Stem rust 1000 bushels	Leaf rust %	Leaf rust 1000 bushels	Stripe rust %	Stripe rust 1000 bushels
CO	14	70.0	980	0.0	0.0	*T	T	T	T
ID	490	79.0	38,710	0.0	0.0	0.2	78.0	0.5	194.9
MN	1,610	55.0	88,550	T	T	**10.0**	9,838.9	T	T
MT	2,850	31.0	88,350	0.0	0.0	T	T	T	T
NE	6	105.0	630	0.0	0.0	0.0	0.0	0.0	0.0
ND	5,950	41.0	243,950	T	T	**3.0**	7,544.8	T	T
OR	175	48.0	8,400	0.0	0.0	1.0	89.4	**5.0**	446.8
SD	1,530	47.0	71,910	0.0	0.0	**2.0**	1,467.6	T	T
UT	12	58.0	696	0.0	0.0	0.0	0.0	0.0	0.0
WA	525	50.0	26,250	0.0	0.0	T	T	**3.0**	811.9
WI	6	42.0	252	0.0	0.0	T	T	0.0	0.0
WY	6	40.0	240	0.0	0.0	0.0	0.0	0.0	0.0
Total from Above									
	13,174	43.2	568,918		T		11,306.5		1,453.6
U.S.% Loss				T		1.94		0.24	
U.S.Total									
	13,174	43.2	568,918						

*T=Trace

DURUM WHEAT

State	1000 acres harvested	Yield in bushels per acre	Production in 1000 of bushels	Losses due to / Losses due to: Stem rust %	Stem rust 1000 bushels	Leaf rust %	Leaf rust 1000 bushels	Stripe rust %	Stripe rust 1000 bushels
AZ	100	97.0	9,603	0.0	0.0	0.0	0.0	0.0	0.0
CA	120	90.0	9,000	0.0	0.0	0.0	0.0	**5.0**	473.7
MN	1	55.0	55	0.0	0.0	0.0	0.0	0.0	0.0
MT	545	33.0	17,985	0.0	0.0	0.0	0.0	0.0	0.0
ND	1,600	33.0	52,800	0.0	0.0	T	T	0.0	0.0
SD	18	25.0	450	0.0	0.0	0.0	0.0	0.0	0.0
Total from Above									
	2,363	38.0	89,893		0.0		T		473.7
U.S. % Loss				0.00		T		0.52	
U.S. Total									
	2,363	38.0	89,893						

Fig. 1. Leaf rust severities in wheat fields in 2004.

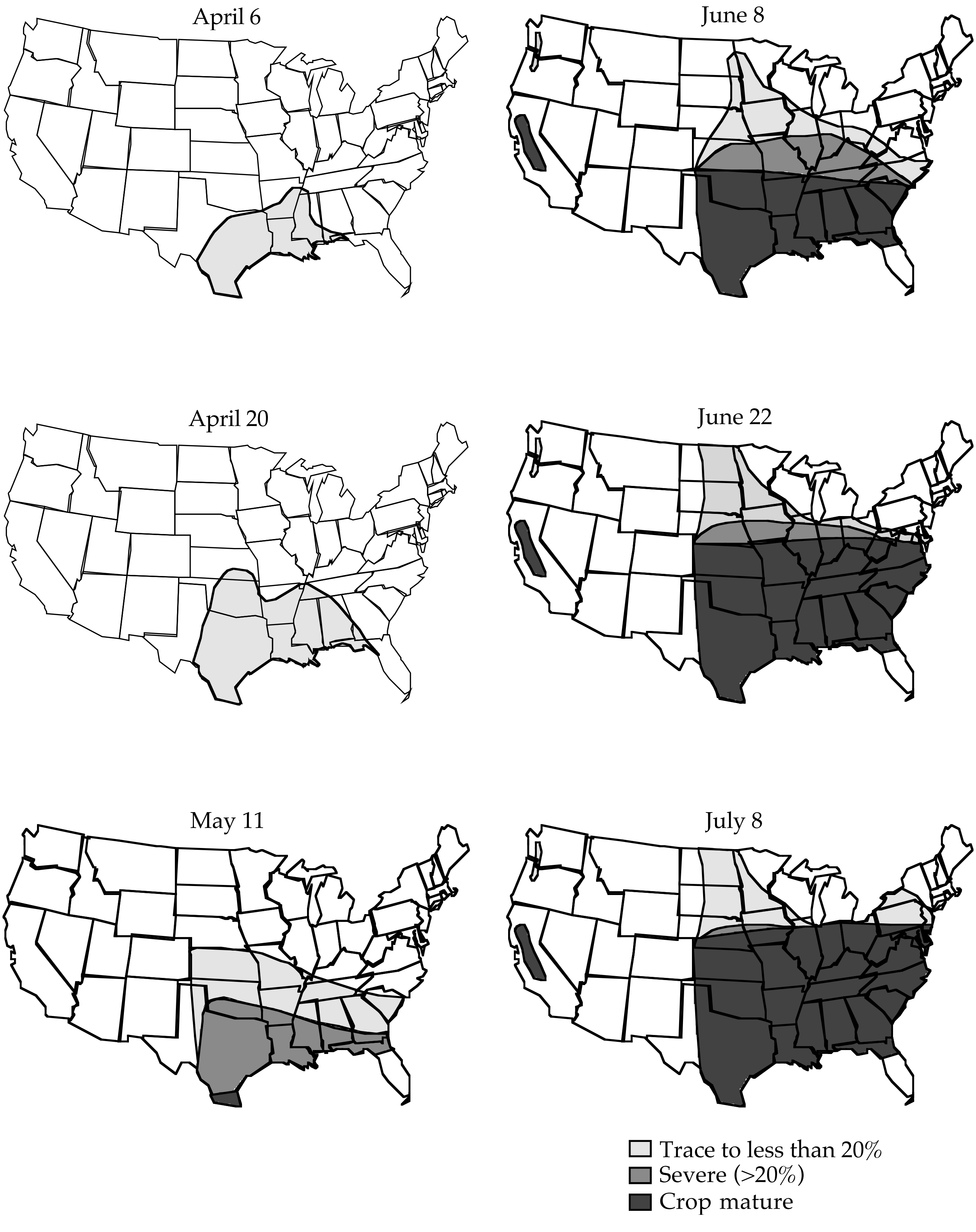

Fig. 2. Stripe rust severities in wheat fields in 2004.

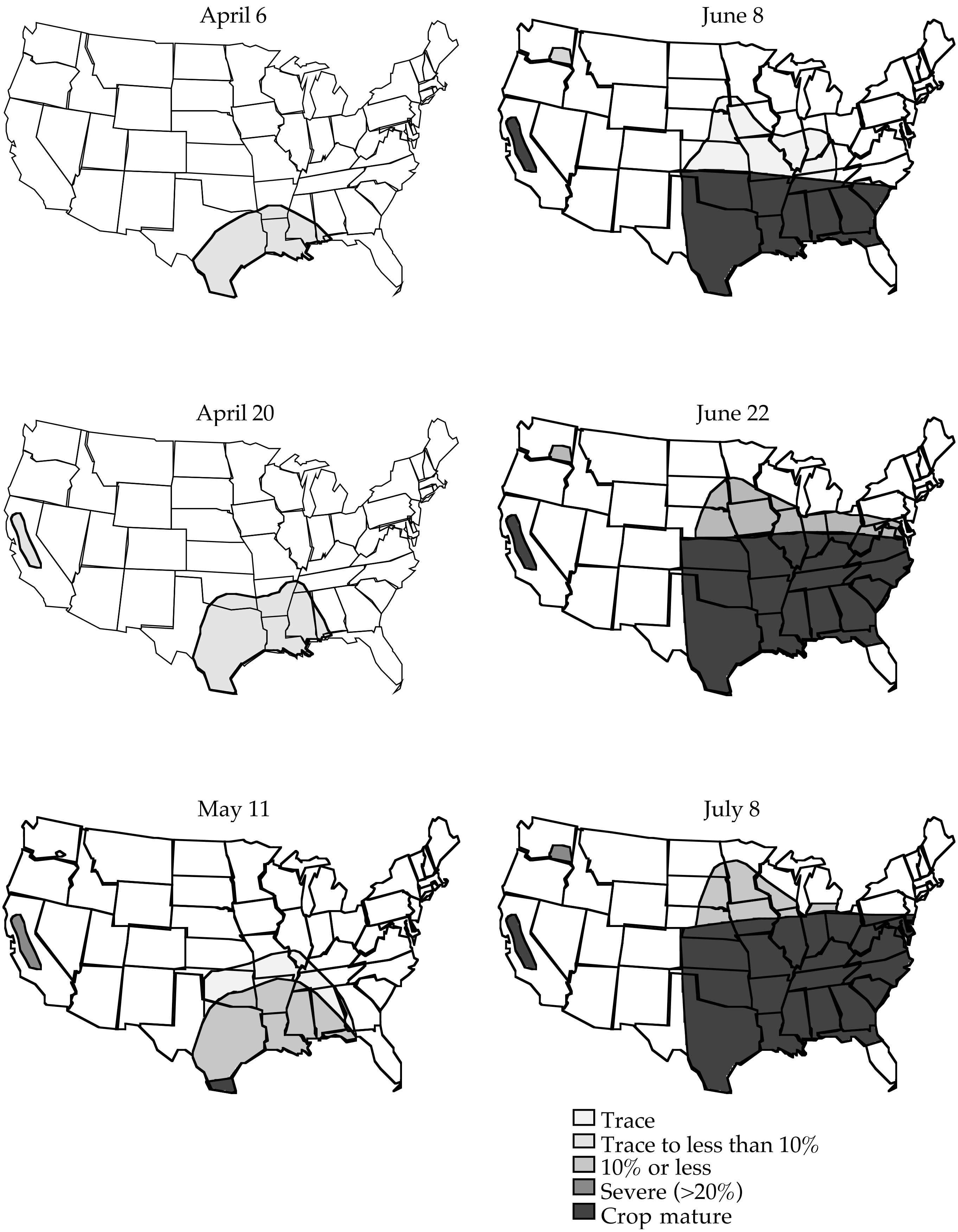

Fig. 3 Agroecological areas for *Puccinia triticina*