B-1053
AUGUST 1966

INFLUENCE ON GRAIN YIELDS AND YIELD COMPONENTS OF LEAF RUST OF WHEAT AND CROWN RUST OF OATS

as measured by

ISOGENIC RESISTANT AND SUSCEPTIBLE LINES

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IN COOPERATION WITH THE U. S. DEPARTMENT OF AGRICULTURE

Contents

Summary

Losses caused by leaf rusts, as expressed in grain yields and percentages, and influences on yield components were determined for oats in 1959 and for wheat from 1962 to 1965. This was facilitated through the growing of isogenic resistant and susceptible lines in yield trials at several locations in Texas.

Where rust infection occurred early or became severe during the fruiting period, oat yields were reduced from 8 to 56 percent, and test weights of the susceptible line were reduced. Wheat yields were reduced from 3 to 29 percent. The number of seed per spike and seed size, as reflected in weight per 500 seed, were reduced on the susceptible line in many instances, but test weight was reduced significantly only where rust infection was high.

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Leaf rust of wheat, *Puccinia recondita* Rob. ex Desm., and crown rust of oats, *Puccinia cornonata* Cda. var. Avenae Fraser and Led. Eriks, are the most destructive diseases of wheat and oats, respectively, in Texas. Owing to the relatively mild winter temperatures in all except the High Plains area of Northwest Texas, the leaf rusts may become established in early fall and persist throughout the winter. Leaf rust frequently overwinters and spreads slowly during the winter as far north as an east-west line from Abilene to Dallas. Crown rust is more sensitive to low temperatures and usually does not overwinter north of the Temple-Waco area of Central Texas.

Serious losses in grain production from rusts are recorded for 1935, 1949, 1957 and 1958. Less extensive losses have occurred in many other seasons, yet the diseases are always a potential threat to the crop. The greatest recorded loss was that of 1949 when it was estimated by Atkins (2) that leaf rust of wheat caused a loss of 12.4 million bushels and crown rust of oats caused a loss of 3 million bushels. Edson et al. (6) estimated that 237,000 bushels of wheat and 954,000 bushels of oats were lost to leaf rusts in 1935. Futrell and Atkins (8) estimated the grain loss of wheat in 1957 at 1.5 million bushels and in 1958 at 2.2 million bushels. Oat losses from crown rust were estimated at 5.8 million bushels in 1957 and 2.6 million bushels in 1958.

The influence of these rusts on forage production, drouth and low temperature survival is poorly documented. It is known that small grain pastures may be destroyed from 30 to 45 days earlier than normal in many seasons by rust epidemics. During the 1962 season, when an estimated 24 percent of the wheat crop in the High Plains area of Texas was winterkilled, it is believed that the heavy infection of leaf rust on this crop greatly influenced survival of wheat. Texas annually seeds more than 6 million acres of small grain of which more than 1 million acres are

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seeded exclusively for livestock pasture. Damage by the rusts is an important consideration in forage use.

The measurement of losses from rust under field conditions is difficult and subject to many errors. Loss estimates in an area or state are especially difficult because of variation in environment and degree of susceptibility of the varieties grown. Most loss estimates for states or areas are based simply on judgement of one or more workers in the area. Comparing fungicide-sprayed plots with unsprayed control plots is one method of measuring the loss. However, this may be difficult to carry out if extended wet periods prevent adequate protection with fungicides and, furthermore, may introduce a third factor which cannot be evaluated, that of control of other diseases. The use of near-isogenic or closely related lines differing only in susceptibility to the particular pathogen offers one means of measuring the influence of the disease on the plant and the damage in terms of reduced grain or forage yields.

Literature Review

The effects of leaf rust and crown rust have been the subject of extensive research. Mains (15) showed that grain yield of wheat could be reduced by 37 percent when 100 percent leaf rust infection developed by the time of flowering. When infection occurred before flowering, the yield was reduced largely by a decrease in the number of kernels per spike, but when infection occurred after flowering, the yield was lowered by a reduction in kernel weight. Johnson and Miller (12) demonstrated with greenhouse plants that yield losses were due to a reduction in number of spikes and in size of kernels. They showed that heavy infection resulted in rapid deterioration of the roots as indicated by root discoloration, a decrease in fibrous roots and a marked loss by root rotting. Peturson et al. (19) found that heavy infections of leaf rust initiated at an early stage of plant development reduced the size and number of kernels in susceptible varieties of wheat. Newton (18) controlled leaf rust on wheat with sulphur dust and found that 40 percent infection of the leaves caused a 10 percent reduction in grain yield.

Murphy et al. (16, 17) demonstrated the important reduction in yield and test weight caused by crown rust infection and proved that rust infection could make plants more susceptible to freeze injury. Recently, Fleischmann and McKenzie (7) reported that 30 percent natural infection of oats at flowering caused a 25 percent reduction in grain yield but, when infection came later than flowering, only 10 percent yield loss resulted.

Isogenic lines as a means of measuring the influence of simple characters on yield or growth of plants was first suggested by Atkins and Mangelsdorf (3) in 1942. The method was demonstrated by comparing grain yields of 10 pairs of awned and awnless isogenic lines of wheat by Norris and Atkins (4). During recent years the method has been used to measure the effects of awns, awn barbing, head-type, growth habit, seed color and other morphological characters on yield, yield components or quality of grain. Craigmiles (5) was the first to measure losses from crown rust utilizing isogenic lines, although Suneson (21) earlier compared yields of back-crossed rust and smut resistant lines of wheat with the susceptible parent variety. Green et al. (9) developed Marquis monogenic wheat lines, which possess one, two or more genes for resistance to stem rust. Johnson and Heyne (13) developed Wichita wheat lines each with a major gene for leaf rust resistance. Similar material has been developed for crown rust by Marr Simons, USDA pathologist at Ames, Iowa[1], and B. J. Roberts, USDA pathologist at St. Paul, Minnesota[2] has developed monogenic oat stem rust lines. Such material offers possibilities for the study of the pathological and physiological characteristics and potentials of the host and pathogen where the effect of one or more genes in a common or diverse background can be determined. The value of isogenic lines in physiologic studies was pointed out and demonstrated by Rowell et al. (20).

Lyles et al. (14) found that 2 stem rust resistant isogenic lines were higher in reducing sugars than their susceptible counterparts. Antonelli and Daly (1) found that isogenic lines resistant to race 56 of stem rust showed essentially the same increase in decarboxylation rates as susceptible lines during the first 2-3 days of infection but subsequently developed values eight times as greast as the susceptible lines. Hilu (11) used isogenic rust resistant and susceptible corn lines to study host-pathogen relationships from initial stages of infection to fruiting of the pathogen.

Weber (22) developed isogenic line pairs of Chippena, Hawkeye, Ford and Clark soybeans with (No) nodulating and (no) nonnodulating characteristics for demonstrating, studying and evaluating the nodulation-nitrogen relationships. Another pair was developed to study the iron utilization efficiency (Fe) and inefficiency (fe) in soybeans.

Although many interesting and valuable studies may be carried out with isogenic lines, a note of caution on their use was made by Harding and Allard (10) who showed that mutations or segregation of characters not observed during development of the isogenic lines may cause errors or inadequate comparisons.

Materials and Methods

Isogenic or closely related lines differing only in one major characteristic may be developed by: Backcrossing

[1]Private correspondence with Marr Simons, USDA pathologist, Iowa State University, Ames, Iowa.

[2]Private correspondence with B. J. Roberts, USDA pathologist, University of Minnesota, St. Paul, Minnesota.

repeatedly to each parental type; selecting a recognizable heterozygote through several generations until all other observable characters become uniform; or selecting in advanced generations in a line which appears morphologically uniform but is segregating for the character one wishes to study. Each method has advantages and disadvantages.

The oat isogenic or closely related lines used in this study were selected from a morphologically uniform progeny row, which was segregating for crown rust reaction, in the sixth generation of the cross Fulwin 2x Lee x Victoria 3x Red Rustproof 4x Victoria x Richard 5x Bond x Rainbow 2x Hajira - Joanette 3x Landhafer. Seed from individual panicles were increased in F_7 progeny rows. The most uniform pairs were increased in F_8 to supply seed of the ninth generation for the 1959 yield trials. The major gene for resistance was that from Landhafer, and the prevalent crown rust races in the nursery at that time were 202, 203, 213 and 216. Races 290 and 294, to which Landhafer and both isogenic lines are susceptible, became prevalent in southern Texas in 1960 so the test was discontinued. The 1959 tests were grown at Beeville, Prairie View and College Station in an area where rust epidemics are common.

The wheat isogenic lines were selected from a morphologically uniform progeny row, which was segregating for leaf rust reaction in the seventh generation of the cross Sinvalocho x Wichita 2x Hope - Cheyenne 3x Wichita, C.I. 12703 4x Kenya Farmer. Seed of individual spikes were increased in progeny rows, and further selected for uniformity in F_8 and F_9 in 1961 and 1962. During 1962, three pairs of isogenic lines were grown at College Station and Denton, and from these the strains 60C4968 (resistant) and 60C4965 (susceptible) were selected as the most uniform and were used in the 1963, 1964 and 1965 tests. The uniform plant type of these strains is shown in Figure 1 while the rust reaction is shown in Figure 2. Milling and baking tests show these strains to have similar quality characteristics.

Figure 1. Showing uniformity of morphological characters of isogenic lines of wheat 60C4965, susceptible, and 60C4968, resistant.

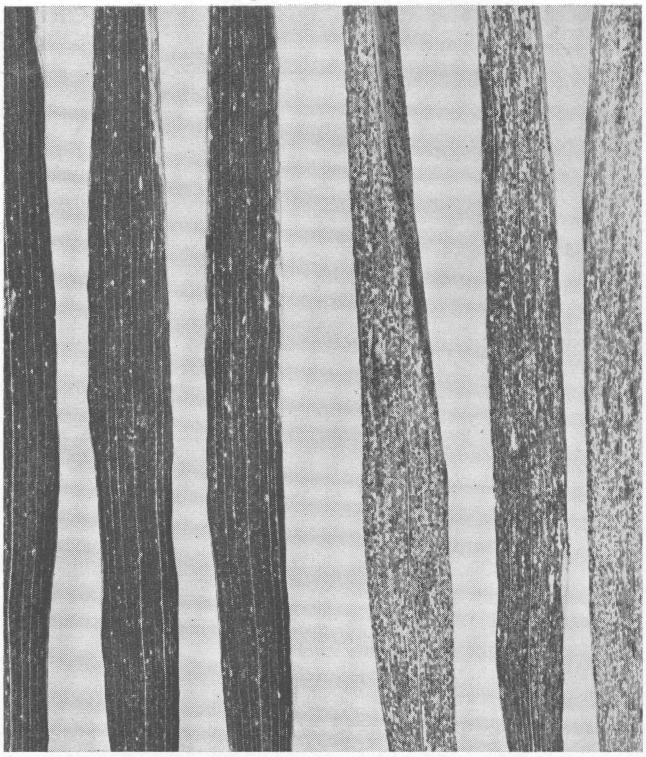


Figure 2. Leaves of isogenic lines of wheat — Selection 60C4968 (left of center), resistant, and Selection 60C4965 (right of center), susceptible.

Races of leaf rust of wheat prevalent in Texas during the testing period of 1963-65 were predominantly UN 2, 5, 9 and 13. Under some conditions, light infection developed on the resistant line late in the growing season but, in most tests, the infection was typical of that shown in Figure 2. Leaf rust notes were taken on several dates during the season to record date of initial infection and rate of spread.

Yield trials of the isogenic lines were conducted as part of the Texas Intra-State Small Grain Performance Trials to determine the prevalence, severity and influence of the leaf rusts and as a basis for estimating losses in Texas. Plantings were made in randomized blocks of four replications, with the request to each cooperator that the pairs be located side by side in each replication. Plots were 4-row, 10-foot nursery plots with 12-inch spacings between rows. Eight feet of the two center rows were harvested for yield and other determinations.

TABLE 1. GRAIN YIELDS, TEST WEIGHT AND CROWN RUST REACTION OF RESISTANT AND SUSCEPTIBLE ISOGENIC LINES OF OATS AT THREE TEXAS LOCATIONS IN 1959

		College Station			Prairie View			Beeville		
Strain	Rust reaction	Grain yield, bushels per acre	Test weight, pounds per bushel	Percent rust	Grain yield, bushels per acre	Test weight, pounds per bushel	Percent rust	Grain yield, bushels per acre	Test weight, pounds per bushel	Percent rust
57C1446	Resistant line	45.4	30	2	33.7	25	0	18.8	25	25
57C1447	Susceptible line	43.8	30	55	22.8	22	100	8.8	23	100
	Diff.-res. vs. susc.	+1.6NS			+10.9[1]			+10.0[1]		
57C1453	Resistant line	50.9	29	Tr	34.6	28	Tr	19.4	25	25
57C1449	Susceptible	45.9	29	58	22.4	23	100	8.2	23	100
	Diff.-res. vs. susc.	+5.0NS			+12.2[1]			+11.2[1]		
57C1462	Resistant line	40.2	32	1	19.9	23	Tr	13.1	26	25
57C1461	Susceptible line	35.7	29	69	13.6	20	100	5.1	23	100
	Diff.-res. vs. slsc.	4.5NS			6.3[2]			+8.0[1]		
Average	Resistant line	45.5	30.3	1	29.3	25.3	Tr	17.1	25.3	25
	Susceptible lines	41.8	29.3	61	19.6	21.7	100	7.4	23.0	100
	Diff.-res. Vs. susc.	+3.7NS			9.7[1]			9.7[1]		
	Reduction in percent	8.4			33.0			56.8		

[1]Significant at the 0.1 percent level
[2]Significant at the .05 percent level

Only grain yields were obtained in the oat trials. As part of a thesis problem by the second author, yield components were determined for the wheat trials in 1963 and for those locations where rust developed in 1964. Stands were determined from culm counts of the entire harvested bundle, kernels per spike from 20 spikes per replication, weight per 500 seed from five samples per plot and test weight from four test samples of the composite grain of all replications. As differences in tillering, kernels per spike, weight per 500 seed and test weight were equal or nonsignificantly different in 1963 where rust was not present, it was considered unnecessary to make these determinations in other years, except where rust influenced yield.

Experimental Results

Oats: Data obtained in 1959 at Beeville, Prairie View and College Station for three pairs of isogenic lines of oats are given in Table 1. The winter season at Beeville was favorable for normal growth until near fruiting time. Crown rust infection occurred during the winter and reached about 40 percent severity before heading time. Reserve moisture was exhaused by heading time, and very little precipitation was received during the fruiting period. Yields were very low but the yields of the susceptible isogenic lines were significantly reduced, averaging 7.4 bushels compared to 17.1 bushels for the three resistant lines or a reduction of 56.8 percent in yield.

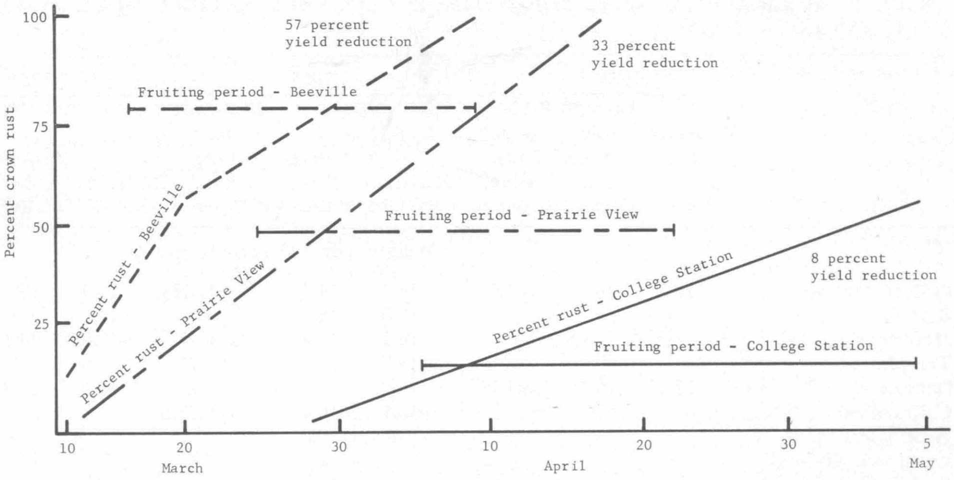
Growing conditions were much more favorable at Prairie View and College Station. Crown rust appeared at Prairie View in the late tiller to boot stage of growth and reached 50 percent infection several days after first head. Near 100 percent infection occurred before maturity and yields were reduced on an average of 33 percent. At College Station rust infection occurred before heading but developed slowly so that a maximum of only 61 percent infection was reached at maturity. Growing conditions for the crop were favorable so yields were reduced only 8 percent on the susceptible lines, and this was not statistically significant. Figure 3 shows graphically the influence of severe early infection on grain yields of oats.

Wheat: Data on grain yields of isogenic lines at a number of locations from 1962 to 1965 are given in Table 2. Yield components data at a smaller number of locations are given in Table 3. Stands, as indicated by number of spike-bearing culms, were determined but differences were nonsignificant in all but one instance. The 1962 planting at College Station showed a smaller number of culms for the resistant lines for some unknown reason.

The experiments were carried out during a period of very dry springs so that rust development was in several instances stopped by dry, windy weather. Rust infection of importance also was generally late in developing so that less damage would be expected.

Data for 1962 are averages of three pairs of isogenic lines at two locations and, though percentages were high, the rust development was mostly after heading of the plants. Yields were reduced at both locations but the loss was relatively small and was nonsignificant at College Station. Weight of seed was reduced significantly on the susceptible line. Number of seed per pike was not significantly reduced although it was lower on the susceptible line at both locations.

Figure. Crown rust development, fruiting period and yield reductions by crown rust on susceptible isogenic lines of oats at three locations in Texas, 1959.



From the three strains tested in 1962, the isogenic pair 60C4965 and 60C4968 were selected as the most uniform morphologically and were used in all tests in 1963, 1964 and 1965. The 1963 season was extremely dry during April and May so that leaf rust, which had been present in light amounts on seedlings, spread very slowly. Figure 4 shows the development of rust in relation to the fruiting period at Beeville, College Station and Temple in 1963. Although rust was present at Beeville long before heading, it reached only 60 percent infection by maturity. Grain yields were very low. The resistant line produced 1.6 bushels per acre more than the susceptible line, which was not statistically significant. Also, both number of seed per spike and weight of seed were greater for the resistant line, although again not significantly greater. The only significant reduction in yield was at College Station where the resistant line yielded 10.9 bushels or 29 percent more than the susceptible line and its test weight was 58.0 pounds compared to 56.5 for the susceptible line. As rust developed early and reached 35 percent infection by heading, the number of seed per spike was significantly reduced and the weight of seed was reduced, but not significantly

TABLE 2. GRAIN YIELDS AND LEAF RUST INFECTION OF RESISTANT AND SUSCEPTIBLE ISOGENIC LINES OF WINTER WHEAT GROWN AT TEXAS LOCATIONS, 1962-65

	1962			1963			1964			1965		
	Resistant average, three lines	Susceptible average, three lines	Resistant vs. Susceptible, difference	Resistant 60C4968	Susceptible 60C4965	Resistant vs. Susceptible, difference	Resistant 60C4968	Susceptible 60C4965	Resistant vs. Susceptible, difference	Resistant 60C4968	Susceptible 60C4965	Resistant vs. Susceptible, difference
Grain yield, bushels per acre												
College Station	18.6	18.5	+0.1NS	37.7	26.8	+10.9[1]	37.1	33.4	+3.7[1]	14.8	11.8	+3.0[1]
Beeville				11.7	10.1	+ 1.6NS	23.0	17.7	+5.3[2]	9.2	6.3	+2.9[1]
McGregor				20.0	20.6	— 0.6NS	42.4	38.4	+4.0NS	25.6	20.0	+5.6[1]
Temple				26.2	25.4	+ 0.8NS	27.3	27.2	+0.1NS	29.6	29.0	+0.6NS
Denton	28.4	27.5	+0.9[1]	24.7	21.9	+ 2.8NS	37.4	30.9	+6.5[1]	26.6	24.1	+2.5[2]
Chillicothe				26.3	23.7	+ 2.6NS	14.6	14.9	—0.3NS	15.5	15.3	+0.2NS
Wellington							10.0	7.2	+2.8NS	8.4	8.3	+0.1NS
Bushland, dryland							13.0	13.2	—0.2NS	Destroyed by hail		
Bushland, irrigated							43.0	39.5	+3.5NS	Destroyed by hail		
Stratford, irrigated							50.7	48.9	+1.8NS	31.6	32.4	—0.8NS
Leaf rust, percent at maturity												
College Station	3	83		33	98		Tr	70		10	90	
Beeville				10R	60		10R	20		10	30	
McGregor				0	Tr		Tr	15		10	100	
Temple				0Tr	45		0	Tr		Tr	100	
Denton	3	67		0	Tr		0Tr	40		20	40	
Chillicothe				0	0		0	0		0	0	
Wellington							0	0		0	0	
Bushland, dryland							0	0				
Bushland, irrigated							0	0				
Stratford, irrigated							0	0		0	0	

[1]Significant at the 0.1 percent level.
[2]Significant at the .05 percent level.

TABLE 3. YIELD COMPONENTS FOR RESISTANT AND SUSCEPTIBLE ISOGENIC LINES OF WINTER GROWN WHEAT AT TEXAS LOCATIONS

	1962			1963			1964			1965		
	Resistant average, three lines	Susceptible average, three lines	Resistant vs. Susceptible, difference	Resistant 60C4968	Susceptible, 60C4965	Resistant vs. Susceptible, difference	Resistant 60C4968	Susceptible, 60C4965	Resistant vs. Susceptible, difference	Resistant 60C4968	Susceptible, 60C4965	Resistant vs. Susceptible, difference
						Weight per 500 kernels, grams						
College Station	17.7	16.1	+1.6[1]	16.4	15.4	+1.0NS	16.9	16.1	+0.8[2]	16.0	15.7	+0.3NS
Beeville				13.0	12.0	+1.0[1]				12.5	10.7	+1.8[1]
McGregor				16.2	16.9	—0.7[1]	17.9	15.3	+2.3[1]	14.6	12.0	+2.6[1]
Temple				18.7	17.0	+1.7[1]				15.8	14.8	+1.0[2]
Denton	17.2	16.1	+1.1[2]	15.2	16.4	—1.2[1]	16.7	15.8	+0.88[1]			
Chillicothe				16.1	16.4	+0.3NS						
Wellington												
Bushland, dryland												
Bushland, irrigated												
Stratford, irrigated												
						Number of seed per spike						
College Station	24.3	22.7	+1.6NS	22.3	18.4	+3.9[1]	21.0	20.8	+0.2NS			
Beeville				17.0	15.6	+1.4NS						
McGregor				14.2	15.7	—1.5NS	26.7	23.9	+2.8[2]			
Temple				16.6	17.2	—1.4NS						
Denton	29.7	28.7	+1.0NS				24.9	23.9	+1.0[2]			
Chillicothe				20.8	18.7	+2.1NS						
Bushland, dryland												
Bushland, irrigated												
Stratford, irrigated												

[1]Significant at the .01 percent level.
[2]Significant at the .05 percent level.

so. Leaf rust infection occurred at Temple about midway of the fruiting period and reached only 45 percent infection at maturity so the effects on yield and yield components were small. Leaf rust did not occur at other stations so damage over the state was only a trace.

The 1964 spring season was again very dry during fruiting of wheat, and rust developed rather late, except at Beeville and College Station. Yields were significantly reduced on the susceptible line at College Station, Beeville and Denton as were number of seed per spike and weight of 500 seed. Although the yield of the susceptible line was reduced at McGregor, variability was high so the difference was not statistically significant. At all stations in the main wheat-growing area of Texas, rust was not a factor in yield, and differences in grain yields between the lines were nonsignificant. The 1965 season was excessively

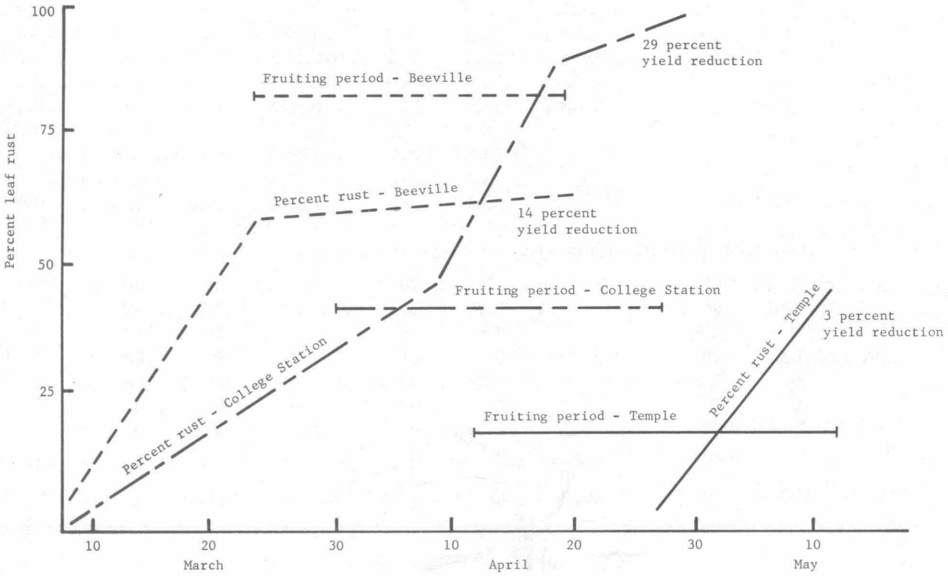


Figure 4. Leaf rust development, fruiting period and yield reductions on susceptible isogenic lines of wheat at three locations in Texas, 1963.

wet during May in Central Texas. Leaf rust infection occurred in the fall and survived to spread slowly during winter. The winter was very mild, so the cold requirement of these lines was not fulfilled and they did not head normally at Beeville. Yields at that station were very low. Grain yields and weight per 500 seed of the susceptible line were significantly reduced at College Station, Beeville, McGregor and Denton. Number of seeds per spike was not obtained in 1965. Leaf rust did not develop to any degree of importance in the Rolling or High Plains, so differences between lines for these stations are non-significant.

Discussion

The use of isogenic lines, differing in disease reaction, appears to provide a practical and efficient method of measuring losses caused by a disease. Where there are rapid changes in races or biotypes of the disease, from season to season, as occurs in the cereal rusts, this presents a problem of providing germ plasm adequate to protect one line and measure the losses. In the present study, the use of the isogenic lines of oats, differing by the Landhafer gene, provided a good measure of rust damage in 1959, but the rapid increase of race 290 and 294 made it impractical to use these lines in 1960.

The isogenic lines of wheat were adequate for measuring losses during the period of study because leaf rust races were fairly stable. The isogenic lines proved to be essentially equal in yielding ability when rust was not a factor. When yields were reduced by rust, this was usually accompanied by a reduction in number of seed per spike and in weight per 500 seed on the susceptible line. This is in agreement with studies by Mains (15), Johnson and Miller (12) and Murphy (17) who have studied the effects of the pathogens and the host under controlled conditions. The great influence which time of rust infection determines was demonstrated in Figures 3 and 4 and confirm the results of Mains (15), Fleishmann (7) and others. Test weights of the wheat lines were not signficantly different in most instances, even when rust was present.

During the 1965 season, when it became apparent that leaf rust would do considerable damage to wheat in Central Texas, estimates were made before harvest by research workers at the stations in the area. These estimates were averaged by R. A. Kilpatrick[3] to give a composite opinion of the loss. This was calculated to be 10 percent for the Central Texas area which grows about 8 percent of the Texas crop. Extended to the state acreage, this represented an estimated 3.5 percent of the Texas crop. The losses, as measured by the isogenic lines, were 20 percent for College Station, 31.5 percent for Beeville, 22 percent for McGregor, 3 percent for Temple and 10 percent for Denton. It should be pointed out that isogenics should be replicated and arranged in pairs so that soil variability in the test will not complicate the measurement of losses. Furthermore, if used on experimental field stations where rust is inoculated into nearby breeding material, the amount of infection and loss may be exaggerated as compared to the commercial crop in the area.

[3]Annual report of research by R. A. Kilpatrick, USDA pathologist, Texas A&M University, College Station.

Acknowledgement

Appreciation is herewith expressed for cooperation in growing the isogenic lines at field stations at Beeville, McGregor, Temple, Denton, Chillicothe, Bushland, Stratford and Wellington, respectively, by the following agronomists: Lucas Reyes, M. J. Norris, U. D Havelka, J. H. Gardenshire, K. A. Lahr and K. B. Porter.

The contents of this publication are a result of cooperative research by the Department of Soil and Crop Sciences, Texas A&M University, and the Crops Research Division, ARS, USDA.

Literature Cited

1. Antonelli, E. and Daly, J. M. Decarboxylation of indoleacetic acid by near-isogenic lines of wheat resistant or susceptible to *Puccinia graminis* f. sp. *tritici*. Phytopathology 56:610-618, June 1966.

2. Atkins, I. M. 1950. Diseases of small grains in Texas in 1949. Plant Dis. Rptr. 34:40-42.

3. Atkins, I. M. and Mangelsdorf, P. C. 1942. The isolation of isogenic lines as a means of measuring the effects of awns and other characters in small grains. Agron. J. 34:667-668.

4. Atkins, I. M. and Norris, M. J. 1955. The influence of awns on yield and certain morphological characters of wheat. Agron. J. 47:218-220.

5. Craigmiles, J. P. 1956. Oat disease studies. Georgia Agr. Exp. Sta. Tech. Bul. N.S. 7.

6. Edson, H. A., Wood, J. I. and Nance, N. W. 1935. Estimate of crop losses from plant diseases in the United States in 1935. Plant Dis. Rptr. Suppl. 94:46-51.

7. Fleischmann, G. F. and McKenzie, R.I.H. 1965. Yield losses in Garry oats infected with crown rust. Phytopathology 55:767-769.

8. Futrell, M. C., Atkins, I. M., and Hobbs, C. D. 1959. Unusual occurrence of small grain diseases in Texas in 1957 and 1958. Plant Dis. Rptr. 43.777-781.

9. Green, G. J., Knott, D. R., Watson, I. A., and Pugsley, A. T. 1960. Seedling reactions to stem rust of lines of Marquis wheat with substituted genes for rust resistance. Canad. J. Pl. Sci. 40:524-538.

10. Harding, J., and Allard, R. W. 1965. Genetic variability in highly inbred isogenic lines of the lima bean. Crop Sci. 5:203-206.

11. Hilu, H. M. 1965. Host-pathogen relationship of *Puccinia sorghi* in nearly isogenic resistant and susceptible seedling corn. Phytopathology 55:563-569.

12. Johnson, C. O., and Miller, E. C. 1931. Effect of leaf rust infection on certain varieties of wheat. J. Am. Soc. Agron. 23:1-12.

13. Johnson, C. O. and Heyne, E. G. 1964. Wichita wheat backcross lines for differential hosts in identifying physiologic races of *Puccinia recondita.* Phytopathology 54:385-388.

14. Lyles, W. E., Futrell, M. C., and Atkins, I. M. 1959. Relation between reaction to race 15B of stem rust and reducing sugars and sucrose in wheat. Phytopathology 49:254-256.

15. Mains, E. B. 1959. Effect of leaf rust *(Puccinia triticiana)* Eriks. on yield of wheat. Phytopathology 49:254-256.

16. Murphy, H. C. 1939. Effect of crown rust and stem rusts on the relative cold resistance of varieties and selections of of oats. Phytopathology 29:763-782.

17. Murphy, H. C., Burnett, L. C., Kingsolver, C. H., Stanton, T. R., and Coffman, F. A. 1940. Relation of crown rust infection to yield, test weight and lodging of oats. Phytopathology 30:808-819.

18. Newton, Margaret. 1938. The cereal rusts in Canada. Empire J. Exp. Agri. 6:125-140.

19. Peturson, B., Newton, Margaret, and Whiteside, A. G. 1945. The effect of leaf rust on the yield and quality of wheat. Canad. J. Agr. Res. 23 Ser. C-D:105-114.

20. Rowell, J. B., Loegering, W. Q. and Powers, H. R., Jr. Genetic model for physiologic studies of mechanisms governing development of infection type in wheat stem rust. Phytopathology 53:932-937, August 1963.

21. Suneson, C. A., Riddle, O. C., and Briggs, F. N. 1941. Yields of varieties of wheat derived by backcrossing. Agron. J. 33:835-840.

22. Weber, C. R. 1966. Nodulating and nonnodulating soybean isolines. Agron. J. 58:43-48.

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