

A SURVEY OF THE SOURCES OF LEAF RUST RESISTANCE
IN WINTER WHEAT VARIETIES AND CROSSES

by

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INTRODUCTION

of the three rusts of wheat, black stem rust, Puccinia graminis tritici, stripe rust, Puccinia glumarum, and orange leaf rust, Puccinia triticina, the leaf rust is undoubtedly the most widespread. It is reported in every wheat growing area. In spite of its world-wide dissemination, it is not considered with as much alarm as either of the other two rusts. The reason for this feeling among farmers, agronomists, and plant pathologists is that this rust is limited to the leaf blades and sheaths except under unusually heavy infection when the stems are attacked. The reduction in yield due to this rust is not so marked as in the case of stem rust, because even under heavy infection leaf rust does not cause shriveling of grain.

REVIEW OF LITERATURE

As early as 1841 Henslow (21) distinguished between stem rust and leaf rust which he called Uredo linearis and Uredo rubigo respectively. He said that the latter was not so destructive to wheat as the former, "wheat mildew," but thought it might be the same organism in a different

stage of fructification. He stated that on the continent rust is more prevalent while in England "mildew" is the more important.

Carleton in 1896 (9) expressed the opinion that leaf rust is of very little importance commercially and in 1899 (10) he said he knew of no well authenticated case of leaf rust causing shriveling of grain. In a letter to William Farrer (14) he stated that leaf rust of wheat known as Puccinia rubigo vera never does serious damage in the United States. From Australia McAlpine (40) voiced the same opinion and William Farrer (14) working on wheat breeding in Australia lamented the fact that he wasted so much time breeding wheat for resistance to this harmless parasite and stated he would no longer work on that problem. Freeman and Johnson in 1911 (16) expressed the opinion that although leaf rust is widespread, extending over the eastern half of the United States, the losses caused by it are not comparable to those caused by stem rust.

More recently losses from leaf rust have been more carefully estimated. In 1917 Melchers (41) reported an estimate of a loss in yield of 33 per cent in Improved Turkey (P706), at Manhattan, Kansas, due to leaf rust which was very abundant on the leaves and peduncles.

In 1919 the United States Department of Agriculture began a definite program of work on this disease in cooperation with Purdue University, Lafayette, Indiana. The Plant Disease Reporter (1) estimated the losses due to leaf rust in the United States as 2.9 per cent or 28,623,000 bushels and in Kansas as 8 per cent or 10,214,000 bushels for the year 1927.

In greenhouse tests under controlled conditions, Wains (23) reported that losses in yield due to leaf rust depended on the severity of infection and on the susceptibility of the varieties grown. When wheat plants are subject to leaf rust throughout their lives, they produce no seed. When infected only in the heading stage, as is most common under field conditions, he found losses in yield ranging from 15 to 25 per cent. On the infected plants grains at the base and tip of the spike failed to fill, due he thought, to starvation.

Johnston* inoculated potted plants of a resistant strain of Pulcaster (Rulhard) and a susceptible strain of

*Johnston, C. O. Effect of leaf rust on yield of wheat in the greenhouse. Annual Report (unpublished). 1926, pp. 72-74.

Effect of leaf rust on yield of wheat in the greenhouse. Annual Report (unpublished). 1927, pp. 97-98. Annual reports filed in Dept. of Botany and Plant Pathology, K.S.A.C. and in Office of Cereal Crops and Diseases, U.S.D.A.

Malakof with form 9 in the greenhouse. He also put uninoculated plants in the moist chamber as checks and carefully measured the differences in yield due to the leaf rust. In both years he got a greatly reduced yield in weight of grains per plant, 22 per cent in 1926 and 53 per cent in 1927. The lower yield in the susceptible variety was due to: a decrease of the number of heads formed, a decrease in number of grains per head, and a reduction of size of individual grains. In neither year was the effect of the rust shown in shriveling of the grain. The Fulcaster plants did not show a decrease in yield due to the rust.

Goulden and Elders (18) studied yield and rust infection statistically in Manitoba. They found a high negative correlation between yield and stem rust infection and lower, but statistically significant, negative correlation between yield and leaf rust infection.

The problem of rust resistance in wheats has received the attention of scientific men for a long time. In this connection it is interesting to see the changes that have taken place in the viewpoint of plant pathologists and plant breeders with respect to the probable basis of resistance. There has been a decided shift from the morpho-

logical to the physiological point of view.

Henslow (21) noted that Uredo rubigo, leaf rust of wheat, was more injurious in the hairy chaffed wheats and more especially in a variety called White-Tunstall. Bolley (4) in Indiana said white wheats produce softer and more succulent straw which is more favorable to growth of the rust parasite.

Cobb in 1892 (12) noted that early wheats escaped rust infection, but so far as he knew no wheat was rust proof. He distinguished between rust proof and rust resistant wheats. He observed that rust resistant varieties have narrow, stiff, upright foliage. The reverse is true of rust liable types. Rust resistant wheats also have a thicker cuticle. He also considered waxy bloom and leaf hairs as aids in rust resistance. Hitchcock and Carleton (22) in Kansas noted the same. Fammel (47) thought the hard wheats were less subject to rust than soft wheats. Tracy (54) in Mississippi in 1893 found all varieties he tested were more or less liable to rust.

Farrer in Australia (14) noted the differences of rust reactions of varieties under different conditions. He postulated on the mechanical type of resistance which may be due to very small stomata not large enough to allow the fun-

gus to gain entrance, or to leaf coverings with waxy substance which prevent enough moisture from collecting on the leaves to allow spore germination, or to leaf epidermis too tough or thick to allow the organism to sporulate, or to erect leaves which prevent spores from staying on them, or to habit of ripening which may prevent the disease from making great progress.

Carlton (10) made some generalized statements about leaf rust resistant wheats. He said they are somewhat dwarfed, close, compact plants with few, narrow, stiff and erect leaves which have a tough dry cuticle often with a glaucous or waxy surface. The heads are compact and the grains are narrow, hard, small and heavy. These characteristics he said were also desired for drought resistance as well. He added the statement, however, that every variety will rust if it matures late. The bearded hybrids from Farrer were more resistant than the awnless ones. Marshall-Ward in 1902 (38) abandoned the physiological hypothesis of rust resistance. He worked with the brown rust Puccinia dispersa on the Brome grasses. He concluded from his work that the size of stoma or the number of stoma has no relation to rust susceptibility. He further showed that rust resistance was independent of other morphological charac-

ters. The factors which govern susceptibility or immunity, he said were the same as those which govern the fertility and sterility of the stigma to pollen.

Bolloy and Pritchard (6) noted the varying reactions of wheats in different localities in 1906 and in 1908. Bolloy (5) was beginning to believe disease resistance was physiological rather than structural.

Butler working in India in 1906 (7) saw the problem of rust resistance in a new light. To him resistance to each kind of rust must be considered separately, for resistance to one does not imply resistance to another. Furthermore, resistance must be worked out in the locality in which the wheat is to be grown.

Biffen was probably the first to study disease resistance from a Mendelian point of view. The wheat rust with which he worked was Puccinia glumarum. He said in 1907 (2) that immunity is independent of any discernible morphological character and it is practicable to breed varieties morphologically similar which are immune or susceptible to attacks of certain parasitic fungi. Fole-Evans in 1911 (48) said that the problem of rust resistance cannot be solved by studying the host plant alone, but the parasite must be studied as well. He cited experiments in which by crossing

a susceptible with a resistant wheat and inoculating the hybrid with rust, it was possible to transfer rust from the hybrid to the resistant parent and get infection. This phenomenon he called "bridging."

However, Biffen did not agree with this interpretation and in 1912 he published a paper (3) in which he showed that susceptible hybrid plants grown side by side with resistant ones had not changed the resistance of the latter in the F_2 generation. He called attention to the fact that Rivet, a rust resistant wheat of England, had maintained its resistance over a long period of time.

Stakman (49) said resistance is probably a delicate balance between host and parasite which is dependent to a certain extent on the environmental conditions.

Since the discovery of physiologic forms of stem rust Stakman and Piemeisel 1917 (50), Melchers and Parker, 1916 (42) of leaf rust, Mains and Jackson in 1921 (34, 35), and stripe rust, Hungerford and Owers in 1923 (24) the problem of breeding wheats for resistance to the rusts has been looked upon in the light of physiologic forms. Knowledge of the presence of distinct physiologic forms did much to explain the reasons for difference of reaction of a variety in different localities.

However, the problem of rust resistance has become more complex than ever before. The inheritance of resistance to single biologic forms of stem rust has often been demonstrated. Mains, Leighty, and Johnston (37) have shown that resistance to physiologic forms of leaf rust also behaves as a Mendelian character.

Mains (36) has reported 12 distinct physiologic forms of leaf rust. He says that resistance is not limited to any group and is found in all types except club wheats, and some club types have been bred for resistance.

The complexity of the problem is becoming greater with our increase of knowledge. Mains, Leighty, and Johnston (37) found that resistance may be either dominant or recessive, depending on the variety and the form of rust used.

Stem rust workers, Goulden, Neatby, and Welch (19) have gone still further and have shown that the same factors, or very closely linked ones, govern the reaction to a number of physiologic forms of rust and that the resistance of one wheat variety to a certain form cannot be combined with the resistance of another variety to another form, because the rust reactions of the two wheats to the two forms are allelemorphic.

Recent developments in the study of rust resistance in wheat make it of prime importance to study the problem with known physiologic forms.

Johnston* has also found strains of wheat which show resistance to a known form of rust while the variety from which these resistant lines were selected is susceptible. In some cases these strains cannot be distinguished from the parent variety morphologically or agronomically.

Another difficulty which may be encountered in breeding for rust resistance is the possibility of the physiologic forms changing or mutating. Pole-Evans (48) called attention to the necessity of studying the fungus in connection with rust resistance. Marshall-Ward (38) said the fungus could be bred and selected as well as the host. Stakman, Parker, and Piemeisel (51) considered that physiologic forms are relatively constant and believed there is nothing to Pole-Evans' bridging hypothesis. Recently, however, Newton and Johnson (46) have discovered a color mutation in a known physiologic form of Puccinia graminis tritici. The virulence or physiologic reactions of the mutants were like those of the parent form.

*Johnston, C. O. The occurrence of strains resistant to leaf rust in certain varieties of wheat. Now in press, Jour. Amer. Soc. Agr. Vol. 21, 1929.

Johnston and Melchers (27) working with known physiologic forms of rust on pure lines of wheat have lately shown that a number of varieties have a constant rust reaction throughout the different stages of growth, while others have changing reactions. Susceptible seedlings usually become more resistant at heading time. The same phenomenon has been demonstrated with stem rust (20). These facts aid in explaining the disparity between field and greenhouse rust reactions and at the same time add difficulty to the general problem of studying rust resistance.

Considerable attention has been paid by a number of investigators to rust resistant and rust susceptible, or in the language of earlier writers, rust liable wheats.

In many cases the reader is left to guess which rust the earlier investigators were writing about.

Bolley (4) working in Indiana found Fulcaster, Dietz, Longberry, and Egyptian, resistant. Velvet Chaff was most susceptible to Puccinia rubigo vera.

Stubbs (53) reported some varieties which remained free or almost free of rust in Louisiana where leaf rust is always prevalent. Those varieties with the least rust were Fulcaster, Golden Cross, Diehl Mediterranean, Purple Straw, and Red Russian. Latta (28) in Illinois reported amount of rust infection in terms of the proportion of

stalks rusted. He did not specify the rust, but it is presumed he had stem rust, since the stalks were diseased. Early Amber showed only 10 per cent rust while some other varieties showed 100 per cent. In 1894 he and Ives (29) made another similar report in which Ohio Bluestem and Nigger were only 20 per cent rusted in comparison to 100 per cent for Fulcaster. Georgeson et al (17) in Kansas tested over 200 varieties and found a number of varieties only slightly rusted. Among those were: Gold Cross, Michigan Amber, Purple Straw, Eversole, Fulcaster, Sibley New Golden, Turkey, and Zimmerman. Nigger was badly rusted.

Pammel (47) reported a number of varieties badly rusted in Iowa. Velvet Chaff and Bluestem were only slightly rusted. In 1890 all the spring wheats were more or less severely rusted and some of the varieties were entirely worthless. Some of the winter varieties showed very little injury due to the rust. These were Turkish wheat, Golden Cross, Red Fultz, Ontario, New Monarch, Fulcaster, and Dietz Longberry. In 1899 Carleton (10) published a very comprehensive study of leaf rust resistance. He studied over 1,200 varieties and strains, many of which were duplications or unfixed hybrids. He listed over 900 varieties which had been tested for three years to leaf rust. In 1895 the nursery was at Garret Park, Maryland. The only

rust present was leaf rust and it was very abundant. In 1896 and 1897 the tests were made near Salina, Kansas, and at Manhattan, Kansas, where both leaf and stem rusts were present, but leaf rust was more prevalent. The winter of 1896 was very severe and many varieties were killed out. In his tables he excluded all varieties tested in one year only. This list of wheats contains many hundreds of wheats which are now unknown.

In addition to this he tested wheats for leaf rust resistance at Lansing, Michigan, 1896, Liberty, Indiana, 1896, Cheyenne Wells, Colorado, 1897, and Bow Creek, Kansas, 1897. Of the winter wheats which proved to be rust resistant to orange leaf rust in the United States he named Turkey, Mennonite, Pringles #5, Rieti, Odessa, and Pringles Defiance; of the spring wheats, Haynes Bluestem, Saskatchewan Fife. The following varieties proved resistant but had not been established: Theiss, Oregon Club, Sonora, Diehl Mediterranean, Fulcaster, Diets Longberry, Arnold's Hybrid and California Spring. Among the introduced varieties not yet fully acclimated he listed Winter Ghirma, Banath, Bearded Winter Budapest, Crimean, and Spring Ghirma. Early varieties which escaped rust were Early May and Zimmerman. Among the varieties which he said were probably worthy of further trial were Early Baart and Kathia. Carleton also

gave an extensive survey of varietal resistance to orange leaf rust found by other investigators in the United States, Canada, Australia, India, and Sweden.

Butler (7) in 1905 said Kathia had proved resistant to the three Indian rusts and had been recommended by Carleton (10) as worthy of further trial.

Berraf was reported by McAlpine (39) to be resistant to stem rust. Only four reports out of 159 said it was heavily infected. In 1905 McAlpine (40) reported Bobs as free from all the rusts except Puccinia triticea.

Carleton (11) called attention to the resistance to rust shown by the durum wheats and also to the great variability even in this group. ~~Emmer~~ and Einkorn were also found to be rust resistant.

Pole-Evans (48) found Bobs which was resistant to rust in Australia (39) to be very susceptible to leaf rust at Pretoria, South Africa, both in the field and greenhouse. It was immune to stem rust at Pretoria, but very susceptible in the low country and other parts of the Transvaal.

Molchers and Parker in 1920 (44) published an account of three Crimean selections, Kanred, P1066, and P1068 which had shown high resistance to leaf rust in the field for six years. In 1919 Kanred was distributed well over the state of Kansas and showed but 10 per cent rust in comparison with

50 to 100 per cent in the case of other varieties in the same year. These authors had previously reported (43) that Kanred was resistant to stem rust.

An extensive survey of the leaf rust percentages of a large number of wheats, both spring and winter, in a number of experiment stations scattered well over the wheat growing area is now in preparation. This contribution will be published as a United States Department of Agriculture bulletin by E. B. Mains, C. E. Leighty, and C. O. Johnston. They have found that Kanred had low rust percentages in some places and high in others. P1066 and P1068 have not been tested extensively since 1925, but they have low rust percentages wherever tested prior to that time. Prelude is susceptible in Indiana, but usually exhibits resistance at other stations. Mediterranean and Temmarq are not uniformly resistant. Democrat and Fulhard are generally resistant in the Southwest. Kawvale is almost uniformly only slightly rusted. Many crosses were tested and these also vary at the different stations. P1066 X Fulcaster, however, usually had only low rust percentages. The Durums were highly resistant. Very low rust percentages were found on all of the varieties of durum wheat tested.

MATERIALS AND METHODS

Field Studies of Varieties

A survey study of the leaf rust percentages of varieties of winter wheats grown in the crop improvement nursery since 1917 was made. The varieties were arranged in alphabetical order and the rust percentages for each year taken from the nursery records. No rust notes were taken in years in which only a light infection occurred.

A similar study was made of the varieties grown in the leaf rust nursery. The records from this nursery were not combined with those from the crop improvement nursery because the land of the leaf rust nursery is low and damp and infection is usually higher than in other fields. Also artificial infection is provided in the leaf rust nursery.

In order to avoid cumbersome figures, the average of the two extremes were used when rust readings were taken covering a considerable range. In case a variety was grown in more than one place in the nursery an average was taken.

Greenhouse Studies

The spring and early summer of 1927 was a very rainy period. As a result, much of the grain in the nursery was

lodged very badly. A heavy infection of leaf rust was present on many of the wheats. A large number of head selections were made in the crop improvement nursery in those rows which showed the greatest freedom from leaf rust. These head selections were threshed individually. It was desired to test these resistant wheats in the greenhouse with a known form of rust. Ten grains were taken from each of the head selections for greenhouse testing. Over seventeen hundred of these pedigree selections were tested in the greenhouse with physiologic form 9 of Puccinia tritici. The remainder of the seed from each head selection was to have been planted in head rows in the nursery. The number was too large to be handled either in the crop improvement nursery or the leaf rust nursery so it was divided, half being consigned to each nursery. However, when the planting list was made out for the crop improvement nursery, it was found that space was not sufficient for all of the selections. A large number were then discarded. These discarded head selections were used to make additional tests of the rust susceptibility of seedling plants.

Most of the head selections were made in hybrid wheats. With each planting of this seed for greenhouse tests, a few pots of both parental varieties were tested also.

The seeds were planted in two-inch pots. The pots were kept in sheet metal pans which were about an inch deep. Each pan held about 100 pots. The plants were supplied with moisture by keeping water in the pans.

When the plants were 10 to 14 days old, they were inoculated with leaf rust. The method used was very similar to that described by Melchers and Parker (45) and Mains (51). The potted plants were placed in a sheet metal cylinder open at both ends and about fifteen inches high. These cylinders were kept under the bench to keep them in the shade. Before the potted plants were put in these moist chambers the ground under the cylinders was thoroughly wetted. The pots were then placed in the cylinders and atomized with tap water. Other plants heavily infected with rust were vigorously shaken over the plants in the moist chamber. This method gives a fairly even and satisfactory distribution of spores over the plants. A pane of greenhouse glass was then placed over the top of the cylinder and left there for 48 hours. The plants were then put back in the pans and allowed to remain for 10 to 12 days, when the rust notes were taken.

Under unfavorable conditions the infection was very poor. In these cases the plants were then reinoculated as soon as it was found that the first inoculation was a failure. Under these conditions wheat mildew, *Erysiphe graminis*

became a very serious pest in that it interfered with clear rust readings. This disease was held in check as much as possible by dusting young plants with "Grape Dust," a sulphur compound dust, after they were inoculated. This was left on until just a few days before the rust pustules were formed. The plants on which the inoculum was propagated were discarded as soon as possible to keep the mildew in check.

The seed available for greenhouse testing in 1927-1928 was necessarily limited, except of the parental wheats. In these latter cases and in the tests made in the greenhouse in 1928-1929, the seed was sown very thickly in the pots to insure a very dense stand of plants.

In 1928-1929 a trial was made of planting the seed in the soil of the greenhouse bench. Rows were made 3 inches apart and 9 inches long in a small groove. The seed was planted and covered about $\frac{1}{2}$ inch with soil and then the bed was sprinkled with water. The seedlings were supplied with water by sprinkling them daily. When the seedlings were about two weeks old they were moistened with a fine spray of water and the inoculum dusted on by shaking pots of heavily rusted plants over them. A heavy muslin canopy was then put up over the plants and kept wet for 48 hours. This method did not prove satisfactory as very poor infection resulted,

and was therefore abandoned. The method has certain time-saving advantages over the other one. As the rust notes were taken the plants were pulled out and a new set of seed was planted immediately.

The degree of susceptibility or immunity was determined by the rust scale used by other investigators, Stakman and Levine (52), Mains (31), and Johnston (26).

0. Immune, many hypersensitive areas or flecks, no uredinia.

1. Highly resistant, few minute uredinia surrounded by yellow necrotic areas, many flecks.

2. Moderately resistant, few to a moderate number of small uredinia accompanied by chlorosis, chlorotic areas occasionally without uredinia.

3. Moderately susceptible, many large uredinia sometimes surrounded by yellowish or green islands, no flecks.

4. Completely susceptible, many large uredinia occasionally surrounded by green islands, no hypersensitive areas or flecks.

Field Studies, 1928

The summer of 1928 was also very favorable for leaf rust infection. The rust notes taken in the leaf rust nursery were very detailed. The rust class, the percentage

of rust on the upper and lower leaves as well as a description of the type of infection were recorded for each strain in the nursery.

In the leaf rust nursery an artificial epidemic was provided by transplanting rusted plants from the greenhouse between the nursery rows about a rod apart and by spraying the field plants with a water suspension of rust spores from the greenhouse.

The only rust notes taken in the crop improvement nursery were percentages of rust for each strain.

The percentage of rust is estimated by use of a scale used by the Office of Cereal Crops and Diseases of the United States Department of Agriculture.

Correlation Studies

A number of correlations were calculated to study the relation of one variable to another. The data were conveniently arranged for each correlation study. Only the correlation coefficients and their probable errors were calculated.

Studies of Reaction to Other Physiologic Forms of Leaf Rust

Bulk seed from some of the leaf rust resistant rows in the 1927 crop improvement nursery was sent to Dr. E. B. Mains at Purdue University to test with physiologic forms 3 and 5. Head selections were made in many of these rows so that it was possible to determine the reaction of many selections to three forms of leaf rust.

Reaction in Different Stages of Growth, 1928-29

It was desired to study the reaction to leaf rust of certain hybrid selections in different stages of growth. About 500 selections were made from seed produced in the field in 1928. Two crosses were used in this study, Kanred X Marquis and Prelude X Kanred. Parent varieties were planted as checks. The seeds were planted in four-inch pots, one seed per pot. When ten days old the plants were inoculated with rust and notes were taken in ten to twelve days. The plants were reinoculated with rust in the heading stage.

EXPERIMENTAL RESULTS

Varietal Studies, 1917-28

The rust percentages for 565 varieties and varietal selections arranged in alphabetic order are presented in Table I. It will be noted that the average rust infection of a variety for the years it was tested is not given, neither is the average percentage of rust for all varieties in each year. Averages were not calculated because they mean very little and are often misleading. This is true especially when the varieties have not all been grown during the same period of years. It is not the average rust in which we are interested.

A very few of the varieties show consistently low rust percentages throughout the period. The following varieties and selections maintained fairly consistently low rust percentages in the years they were tested: Alaska Winter, CI 5873 (Triticum turgidum); Crimean, Kans. 2489; Fulcaster #4, Kans. 2621; Fulcaster #11, Kans. 2623; Fulcaster #21, Kans. 2622; Fullard, CI 8257; Fultz, CI 5308 (except in 1923); Hungarian, CI 3299-1M; Indiana Swamp (later named Kawvale), Kans. 62 (except in 1919); Kanmarq Sel. 215088; Kawvale, CI 8180; Kharkov, Kans. 282; Kofoid, CI 4337

(except 1927); Mediterranean, CI 3332; Menno, Kans. 496; Odessa, CI 3274 (not tested since 1922); Oro, CI 8220 (tested only in 1928, but resistant in both nurseries); Prelude, Kans. 352-2; Purkof, Kans. 2612; Turkey, Kans. 2473; and Winter King, CI 3546. The selections Kanred, P1066 and P1068 showed considerable field resistance until 1922. Since then they have been more or less susceptible.

Table I Leaf rust percentages of winter wheats grown in the crop improvement and leaf rust nurseries, Manhattan, Kansas, 1917-1928.

Variety	No.	No. 1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	Crop Improvement Nursery		Percent of leaf rust infection	
Ahrens	164	4848-1				
Alabama	5785		90		85	50
Alaska Winter	5673		50	5		40
Alberta Red	20					
"	268	24:	40			
"	2050	32	45			
"	2238	45	60			
"	2239	90				
"	2269	35				
"	203220					
Altera	2048		67	55	74	90
Alton	395		50	65	40	85
Amavir	269	24		65	40	85
American Bronze	71	5380	95			
"	2558	5380	65	85	85	
Argentine	2217		40			
Arnavir	2200		75			
"	2204		65			
"	2205		75			
Island	428					
				85		85
					70	80
						60

When rust percentage notes were taken in ranges, the figure used is the average of the two extremes. Percentages not in multiples of 5 are averages of more than two rows.

Variety	No.	Mo.	Percent of leaf rust infection												
			Crop Improvement Nursery					Leaf Rust Nursery							
Kansas: C. I.															
No.	Mo.	1917	1919	1921	1922	1923	1927	1928	1922	1923	1925	1926	1927	1928	
Ashkov	2518	6680													
Awless Selection	376				70	40	90								
Awless Turkey	420						85								
"	421						85								
"	422						90								
Baaska	326	6156			32	55	50	52							
"	2286				87										
Banat	1634	1560		25	50				70	75	70	50		36	
"	4879														
Banatka	2150				85										
Bannock	2285	1560			75										
Barletta No. 24	5999														
Bart	2381					50	80	80		60	80		95		
Bearded Pife	5302-1														
Bearded White Pife	4202			36	67	60	50	80							
Belogilna	60														
"	1543												95	80	
"	2419	1544			47					90	85	80	70		
"	2251	1667			35	55	75	80	95			90	70	80	
"	2239											85	80	70	
"	2251	1667			35	50	27	75	100			90	95		
"	2255	2239B			50										
"	2268	2239C			85										
"	2273	1543-6-10			52										

Variety	No.	C. I.	Percent of leaf rust infection				
			Crop Improvement Nursery		Leaf Rust Nursery		
			:	:	:	:	:
Beloglina	2427	1543	40	45			
"	2592	1543			100		
Beardless Winter Pife	129		40				
Bearded Purple Straw	109		90				
Berg (Turkey)	2475		40	55	50	70	
Berkeley Rock	2515						
Big Frame	271		95	75	70		
Binkel (a Club wheat)	2353		40	45	55	80	
Black Awn Turkey	425						
Blackball	306		56				
Blackball	343	6251	50	42	55	58	64
" Sel.	3028					43	
" "	3029					45	
" "	3031					40	
Black Turkey	479					85	
Blue Chaff	2501	6262	70				
Bokara	302		60				
Bosnian	2279	1691					
Brown Bearded			75				
Brown Chaff Crimean	361						
Bucanera	2404		21	60			
Budapest	74	4380	95				
Buffum No. 17	2351	3330	39	43	63	85	92
						65	85
							95
							80
							70

Variety	No.	C. I.	Percent of leaf rust infection									
			Crop Improvement Nursery					Leaf Rust Nursery				
			1917	1919	1921	1922	1923	1927	1928	1922	1923	1925
Barbank Super	388	1367				75	70	70	70	70	70	80
Burnatka	503	6201		58	50							
"	342				60							
Chapanka	1183	3052		24	90							
"	2138			36	85							
"	2139				85							
"	2340				62							
"	2341				95							
China	108				95	65	60	90				
Clyde									25			
Cooperatoroka	490								70			70
Copper						60	80	90				
Corniel	2319	3088		85								
Cox						65	75	90				
Crimean	393	1583B				65	80	80				
"	394	5032				65	80	75				
"	395	3055				65	80	90				
"	396	2578-1				65	15	90				
"	397	2576-A				65	60	90				
"	398	2191-1				65	80	85				
"	845	6208		51	67	55						
"	1627	1435		22	56							
"	2207	1435		50	50	55	60	80		80	80	
"	2214	1559-3-09		75								

Variety	No.	No.	Kansas: G. I.	Crop Improvement Nursery	Percent of leaf rust infection
Orimean	2263	1437B	70		
"	2389	1437			
"	2488		45	40	
"	2489		50	60	
Growth's Red Chaff					
Gurrell	2157		72		70
"	2406		75		
Darlington (Blackhall)	2610	3326			
Dawson's Golden Chaff	78	3342	85	85	80
Defiance Winter (Turkey)	373	6205	90	60	85
"	2121		80	77	
"	2122		62		
"	2123		60		
"	2130		68		
Democrat	3394				
Denton	Sel. 3015-66		60	60	85
"	2624				
Diamond	5710			45	
Diamond Grif	3385		65	80	
Diehl Mediterranean	1359		65	50	90
"					
"	2173		82		
"	2175		55	45	50
Diets	1961			60	70

Variety	Kansas: C. I. No.	Percent of leaf rust infection	Crop Improvement Nursery	Leaf Rust Nursery
	No.	1917:1919:1921:1922:1923:1927:1928:1928:1923:1926:1927:1928:		
Diets Longberry	5570	45	85	
Diamond	2281	70	77	
Douglas	324			50 70
Early Arcadian	3390	65 85 75		
Early Blackhull	485		20	70
Early Genesee Giant	38-1 1744			65 70
Early Harvest	2551			
Early Kenred	2521	40		
"	2599	100		
Early Oakley	2559	65 90 90		80 95 80
Early Red Chaff	3392	65 40 75		80 25
Early Red Clawson	2577 3393	60 60 80		55 25 70
Early Ripe	72 5350	95		
Early to Ripen	430	90		73 40 30 30
Elipse	5574			50 85
Economy	3397	85		90
English Squarehead	3317	85		
Erie Sel. 255790		90 70		80
" " 255794		80		
" " 255796		80		
" " 255798		90		
" " 255811		45		
Eureka	2195 5170	40 60 65		80 90
Evans	2946			40 45 50 70

Variety	No.	C. I.	Percent of leaf rust infection				
			1917	1918	1919	1920	1921
Eversole	1124	3011					
Extra Early Windsor	2566	5915					
Farmer's Trust	3346						
Fern	2422	38					
Flint	2562	6306					
Florence	358						
Forty-Fold	202						
Forward	2523	91					
Friend							
Fulcaster Red. 47-2-34-7-6-2	55						
"	317	6471					
"	426						
"							
"							
"							
"	2620						
HW 2-225							
No. 4							
" 7	2621						
" 11	2623						
" 21	2622						
" 33							
" 55	2623						
Fulhard	2594	8257					

Variety	No.	No.	C. I.	Percent of leaf rust infection				
				Crop Improvement Nursery	Leaf Rust Nursery			
				1917:1919:1921:1922:1923:1927:1928:1928:1928:1928:1928:1928:	1923:1925:1926:1927:1928:			
Fulbio	2548					90	95	70
Fultz	53			80				
"	316			20 25 60 80	30			
"	2155			75				
"	2156	6215		77 60 85 85	90	95	80	60
"	2561	3416					95	70
"		3415		65 90 90				
"		4899			95	85		
"		5308				85	tr	7 10
Fulso-Mediterranean		4811		55 85 85				
"		5353			40	90		
Genesee Giant	1744			65	70			
Chirka Winter	360	1438		65 75 85				
"	2181			75				
Giant Squarehead	88	5273		90				
Girgeh	2219			70				
"	2220			70				
Gladden	2545							
"		3544			85			
Gleason		6978		65 80 90		90	50	50 70
Gluten	2584							
Gluten B86								
Goens	2584	4856		65 80 85		45	90	60
Going		4957		65 75 90 40			55	70 50
								35

Variety	No.	No. : 1917:1918:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	Percent of leaf rust infection									
			Crop Improvement Nursery					Leaf Rust Nursery				
Gold Coin	2517	2966	65	65	60			35	55	62		
Gold Drop	2568	6317	65	80	85			80	57			
Golden Chaff	2573	5578	65	70	90			40	72	70		
Golden Rod	185		72	50								
Golden Wave	6884							40	70	65		
Grand Prize	2579	4876	65	60	85			tr	15	65		
Grass	2569	6027	70	65	90			80				
Gypsy	245	3426	95	65	75	90						
"	5579							60	70	60		
"	5960		65	65					32			
Hard Red Winter	2059											
Harold	6005		60	90	87							
Harvest Queen	19	6199	66	57	85	80	60	70	65	76	45	45
"	4882								50			
"	5314								90			
Hickman	5313							40	85			
Homer	6328		70	40	60							
Honor	2522							90	85	80		
Hudesti Novi	2371		60									
Hungarian	2194		29	85								
"	3299-1M											
"	4830											
Hungarian Turkey	2262	4611	75									
								85	35	45	25	10
											70	

Variety	No.	Sel.	C. I.	Percent of leaf rust infection									
				Crop Improvement Nursery					Leaf Rust Nursery				
				1917	1919	1921	1922	1923	1924	1925	1926	1927	1928
Hybrid No. 60	5024												
" No. 128	348												
Huesar	4512												
Illini Chief	353												
"	4843												
"	223												
"	6200												
"	1729												
"	Sel. 3297												
"	Sel. 3315												
"	5406												
"	5956-1												
"	Sel. 193287												
"	" 223415												
Imperial Amber	4960												
"	2588												
Improved Turkey	5338												
Indiana Hybrid	2382												
Indiana Hybrid	5592												
Indiana Red Wave	132												
Indiana Sel. No. 18	309												
Indiana Swamp	141												
"	62												
Iobred	5274												
Iobred	4834												
Iobred	431												
Iobred	6934												
Iowa No. 1946	347												
Iowa Red Winter	6676												
"	2368												

Variety	No.	Kansas: C. I.	Crop Improvement Nursery	Percent of leaf rust infection
		: 1917:1919:1921:1922:1923:1927:1928:	: : : : : : : :	: : : : : : : :
Ironclad	7		45 45 65 80	85
Japanischer	2356		50	
Japan Winter	2410	34	15	
Japhet	2437		65	
Johnson	2439		87	
Jolly Farmer	5558			30 85 5
Jones Bearded Wife	229		95	
Jones Climax	308	6203	35 62 50 80	
Jones Fife	4468		65 80 85	
Jones Longberry No. 1	249	5923	95 65 35 85	87
Jones Mammoth Amber	478	3551		
Jones Winter Fife	200		95	
Kamarq	440	6937		33 33
" Sel. 215088			tr	5
Kanred	2401	5146	11 5 3 5-	75 64 41 78 45 53 46 60
" Sel.	2531			
" Field Hybrid				
Kansas	341	4896		82
Kansas Mortgage Lifter	104		70 45	85 60 40 75 56
Karmont	2250	6700	90 55 85 75	
Karvale	2593	8180	85 45 50 60	85
K. B. No. 2	58	4835		70 85 77 70 65 5 10
Keystone	259		70 90 90	13 5
Kharkov	35	1442	95	70
"	282		15 43 60 35	75 45 70
			21 50 50 30	50

Variety	No.	No.	Percent of leaf rust infection											
			Crop Improvement Nursery						Leaf Rust Nursery					
Kansas: C. I.			1917	1919	1921	1922	1923	1927	1928	1922	1923	1926	1927	1928
Kharkov	327	25												
"	382	6206	15	67	20	25	40	18		80	85			70
"	418	6686					72				85			
"	1443	6209	34	25										
"	2001		30	78										
"	2002		26	55										
"	2013		21	57										
"	2210	1442		55	45	40	60	80				70	70	
"	2211	1442-15-09	65											
"	2221	1583	80											
"	2222	1583-4-09	55	45										
"	2228	2193	75											
"	2229	2208-2-1	65											
"	2247	14423	70											
"	2539	6938						87				60	80	
"	2540	6939										85	80	70
"	2541	6940										85	85	85
"	2591	1442						87	50					
Blondyke	125	4861	95											
Xofoid		4337												
Lancaster		1945						tr	40			tr	80	
Lancaster-Fulcaster		3455	93									35	85	
Lars Peterson	136							70	75	90				

Variety	No.	C. I.	Percent of leaf rust infection									
			Crop Improvement Nursery					Leaf Rust Nursery				
			1917	1919	1921	1922	1923	1927	1928	1922	1923	1925
Laurence	2502					65	90			95	80	80
Leap	429	4823				65	90	90				
Lebanon	3456								40	80		
Lincal	2613											40
"	2614											40
Lofthouse	3275					70	70	85				
Logan	491											
Lutescens	113								70		50	80
Malakoy	284	6470	24	57	60	35						70
"	2071	6210	65	60	50	40	40	78		40	50	70
"	2258	2908		85								
"	2474			35	50		70					
"	2518	6680				70	80					
"	4898									65	60	30
"	6470										80	70
"	6680										70	70
"	6938										80	80
Mammoth Amber	3355					65	45	85				
Mammoth Red	2517	2008-16-14					65					
"	5587									65	85	10
Martin	4463										30	50
Martin Amber	4636					70	75	85		45		70
Nealy	69	3358	95	65	75	85						65

Variety	No.	1917:1919:1921:1922:1923:1927:1928:1928:1927:1928:	Crop Improvement Nursery	Percent of leaf rust infection	Leaf Rust Nursery
Marvelous	105	95			
Mediterranean Sel.	312				
"	315	5303			
"	427		50		
"	No. 30		77		
"			70		
"			45		
"				80	
"				80	
"				50	
"				65	
"					
Menno	496		29		
Michigan Amber Sel. 29-1-1					
" " B45-1					
"		4864			
"					
"	2438				
"	2533				
"	2534				
"	2535				
"	2525				
"	2542				
Michikov			70		
Minard					
Minardi					
Minnesota No. 1495					
(Turkey x Odessa)					
Minnesota No. 1496					
(Turkey x Odessa)					

Variety	No.	No.	C. I.	Crop Improvement Nursery					Percent of leaf rust infection				
				1917	1919	1921	1922	1923	1927	1928	1929	1930	1931
Minnesota No. 1498 (Turkey x Odessa)	2452					55							
Minnesota No. 1509 (Turkey x Odessa)	2453					45							
Minnesota No. 1549													
Minturki	2448												
"	2464	6155		30	50	72	80				80	85	80
Miracle	54	5665		40	55	85	80	87			95	70	70
Missing Link	144	4866		90							85		80
Mocasin Sel.	2296	4433-2			60	65	80				50	80	
Montana No. 36 (Kharkov)	2472	5549				70	80				50	90	
Moro Sel.	2306	2979-B		40	45	65	42	80			70	85	70
Mosida	2538	6688				80	90						
Nebraska No. 6	321	6289		35	55	60	65	70			85		
Nebraska No. 10	323			30	50			85	60		65	70	50
Nebraska No. 60	322	6250		40	57	80	76	88			88	85	70
Nebraska No. 70	324			35	60								30
Nebraska No. 253	325			40	60								80
Nebraska Hybrid No. 28	34	5147		65	56	87	56	92			90	85	50
Nephi	2327	4541				15	55	35			70	60	80
New Amber Longberry		1973		65	40	80							50
Newton	1214	5300				65	60				90	85	
Newark	2596	6955											80
Nigger	255	5366		90	65	80	90	85	50				

Variety	No.	No. : 1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	Crop Improvement Nursery				Percent of leaf rust infection			
			1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:
Nigger	459	5366								
Nittany (Penn. No. 44)	400	4867					10	70		90 95 95
Nixon	2405	3481	65	55					40 85 25 30 45	
North Allerton	307	5580	75	65	75	90			40 65	
Oatka Chief	551									
Odessa	2385	3003	65	72	85	90				
"	2465	6151		67	45					
"	2507	4482C	90	70	67	90	95		85 95 80	
"	2508	4492D		70	50					
"	2509	4475	90	65	60					
"	2510	4472B	90	70	40					
"	2511	4470A	90	75	60					
"	2512	3274	10	10	50					
"	2513			65	30					
"	2514			40						
"	4335		90							
"	4475		90	70	60	90				
"	5240		90	65						
"	5241		90							
"	6151		40							
Ohio	2546	9920					96			90 95 70

Variety	No.	Kans.	Crop Improvement Nursery	Percent of leaf rust infection
Ontario Wonder	256	3843	70 80 95	50
Oro	495	8220		60
P721 (Grisean)	2390	1438	3 40	20
"	2494		10	
P751 "	2496		10	
P1086 "	2415	5879	5 9 3 5-	40
P1088 "	2414	5880	13 4 6 33	60
Fadmi (Red Chaff)	2467	6163	45 50 63 85 90	85 70
Peck				85 80
Pennsylvania Bluestem	94			15
Peterboden	205		90	
"	1635	1564	26 65	
"	2276	1564	38 55	
Pete Buft(Turkey)			80	70
Poole	257		91	
"	314		40	
"	2576	3488	65 80 90	55 80
"		3336		95 80
Portage	2544			20 40
Prolude Sol.	352-2			
Prohibition	4068		75 80 90	
Prosperity	1025		50	

Variety	No.	No.	No.	Percent of leaf rust infection									
				Crop Improvement Nursery					Leaf Rust Nursery				
Kansas: O. I.													
No.	No.	No.	No.	1917:1919:1921:1922:1923:1927:1928:1928:1925:1926:1927:1928:									
Purkof	2612					40				20	40	70	
Purple Straw													
Red Chaff	2572	6364			55	85	85						
Red Cross	61			65	50				90				
Red Hull	487												
Red May		5336			65	80	90					50	
Red Resa		6390			65	5	25						
Red Reseca		6390											
Red Rock	310	5597			50	35	90		70	90	50	60	
Red Russian		4509				90	85						
Red Sea	266			62									
Red Wave	157			90									
" "	2570	3500			65	40	80			35	52	70	
Red Winter	196			21	50								
" "	839			29	67								
" "	2101	6213		26	40								
" "	2132			38	47			80	60		85	80	
" "	2358				60								
" "	2368				60	90							
Red Wonder	5817								80	90			
Red's Winter	2589	6401			60	40	85						
Regal	2609	7364										80	
Regenerated Defiance	2342			95									

Variety	No.	C. I.	Percent of leaf rust infection					Leaf Rust Nursery	Leaf Rust Nursery	1926:1927:1928:
			1917:1919:	1921:1922:1923:	1927:1928:	1922:1923:1925:	1926:1927:1928:			
Rice	2556	3734		70	22	23				
Ridit	2543	6703								
Rivst	4201			45	tr	40	70	60	80	36 50
Rochester	258		90							
" Red				65	65	80				
Romanella	2412	2479	30	75						
Romanian	829	1656	72							
Row No. 959	438	2553								
Rudy	2583	4873								
Empert's Giant	2571	5920		65	75	85	40			60 70
Rural New Yorker No. 6		5921		65	50	75				55 35 60 70
" " No. 57		3516		65	70	95				
Russian	2587	5737		60	40	90				32 47 70
Rust Proof		6263		60	25	25				
Schottischer Bank	2417		22	50						
Sedgwick (Blackbull)	2611	8262					65	50		
Seneca Chief		3575								
Servian	2202	1728-4-1-10	80				65	75	90	
"	2278	1679-1-2	65							
Sherrif	2421		35							
Shepherd	435	6163								50 50 50 65
Shepherd Prolific	3579						5	50	90	25 70

Variety	No.	No. : 1917:1919:1921:1922:1923:1927:1928:1922:1923:1925:1926:1927:1928:	Percent of leaf rust infection			
			Crop Improvement Nursery	Leaf Rust Nursery		
Sherman	2270	4430	5	80	90	80
"	2520	4430		50		
Schonacker	2565	5942	70	70	75	
Sibley		5666-5A-2				60
Sibley's New Golden	2088	5666	75	10	60	85
"		3520				85
Silver Sheaf		2496	65	85	85	75
"	2565-8					60
" " Longberry	86		91			
Smith Rust Proof	3588		70	60	80	
Sol	6009			90	90	
Squarced Master	3283					80
Station Red			35	55	50	70
Stepinatchka	350					80
St. Louis Grandprise	493					
Stoner (Miracle)	152		90			60
Stranger No. 2	349					45
Superhard Blackhull	470		65	75	90	85
Tauranian	304	6202	57		57	53
Tennary	439	6936			55	46
"	2637					
Theiss	2215		71	45		30
"	2249		60			
Titano	5535		30	tr		

Variety	No.	No.	Kansas: C. I.	Percent of leaf rust infection				
				Crop Improvement Nursery	Leaf Rust Nursery	Leaf Rust Nursery	Leaf Rust Nursery	Leaf Rust Nursery
Turkey	2029	30	65					
"	2035	33	85					
"	2039	31	87					
"	2042	17	55					
"	2098	36	65	75				
"	2218	1571	65					
"	2230	2223	75					
"	2235	2922	75					
"	2240	2998	65					
"	2241		85					
"	2242	4428	35	50				
"	2260	2998I	75					
"	2261	4429	65					
"	2265	1571B	75					
"	2297	1571-910		50	90			
"	2343	1750	55					
"	2409	6217	40					
"	2424	1658	75					
"	2429	1571	77					
"	2430		75					
"	2431		80					
"	2456	6152	40	52	85	93	90	85
"	2473		40	45	30			75

Variety	No.	C. I.	Percent of leaf rust infection									
			Crop Improvement Nursery					Leaf Rust Nursery				
			1917	1919	1921	1922	1923	1927	1928	1922	1925	1926
Turkey	2490		40	45	80							
"	2491		55	50	70							
"	2492		10	5	65						95	70
"	2493		40									
"	2499			65	80	70						
"	2532	7005					100			90	80	70
"	3015											
"	3055						98				70	80
Turkey Red	57		70									
"	221		80									
"	291		38	65								
"	2050		65									
"	2054		50									
"	2105		38	52								
Turkish Amber	480	5929						27	35	90	15	55
Ukraine	492							40			60	60
Uita	2434											
Valley	98	5376	75							60	80	40
"	70	5925	85	70								70
Velvet Chaff	175	5948	88	65	70	90						
"	2590											
V.P.I. No. 112	433									85	35	60
" No. 131	434									45	35	50

Variety	No.	No.	Crop Improvement Nursery	Percent of leaf rust infection
Weismberg	293	28	65	
"		1563		
"	2216	85		80
"	2275	70		
"	2287	75		
Wheeling	2574	65	90	80
Wheeler	311	40	90	60
Wheeler's Aimless	312	50	90	90
"	2500	60	90	85
White Odessa		4481C		
"		4482D		
"		4651		
"		4655		
"		4771B		
White Winter		5219	60	90
Winter Bluestem		5904	65	75
Winter Fife	129	81	40	
Winter King		3546		
Winter Marquis	2550		76	100
Winter Preston	391	6677	69	25
Wisconsin Pedigree No. 2	318	35	3	95
"	319	40	75	80
"	320	60	50	
"				
Sel. 622		6680		85

Greenhouse Studies with Leaf Rust Physiologic Form 9

The greenhouse studies were made with physiologic form 9. A summary of the reactions of seedling plants from seed of the head selections is presented in Table II. In this table the rust reactions are grouped into susceptible (sus.), intermediate (int.), resistant (res.), and segregating (seg.) classes. This table shows that in the seedling stage most of these selections were susceptible to physiologic form 9. The varieties showing resistance were Fulcaster, RN 11, Kans. 2623; Kawvale, CI 8180; and Winter King, CI 3546. It will be noted that most of the selections of the cross Kanred X Hard Federation contained resistant plants, there being 219 resistant lines out of a total of 223. In the cross Kanred X Fulcaster many resistant selections were found. — Of 291 selections tested, 269 contained resistant plants. Four selections of Kanred X Fulcaster were susceptible, three were intermediate and fifteen were segregating. In the segregating selections most of the plants were resistant. The cross P1063 X Fulcaster is very similar to the Kanred X Fulcaster in rust reaction.

Table II.--Summary of the leaf rust reactions to physiologic form 9 of varieties and crosses tested in the greenhouse, 1927-28, and in the field, 1928.

Variety or cross	Total :			Segregating head		
	number:	of	head	selections	of	selections
	number :	head :	number :	selections :	number :	of plants :
	of :	selec- :	of :	of :	of :	of :
	strains :	plants :	susc. int. :	res. seg. :	susc. int. :	res. seg. :
Farmers Trust	: 1	: 11	: 86	: 11	: :	: :
Pulcaster RM 11	: 1	: 11	: 83	: 1	: 10	: :
Illini Chief	: 2	: 20	: 196	: 20	: :	: :
Kawvale	: 1	: 15	: 141	: :	: 15	: :
Menno	: 1	: 15	: 136	: 15	: :	: :
Riddit	: 1	: 10	: 92	: 10*	: :	: :
Shepherd Prolific	: 1	: 10	: 89	: 10	: :	: :
Winter King	: 1	: 10	: 90	: :	: 10	: :
C. E. Leighty Sel.	: 3	: 33	: 223	: 33	: :	: :
Kannarg	: 1	: 15	: 140	: 15*	: :	: :
Kanred X Marquis	: 11	: 116	: 991	: 86	: 30	: :
Pl066 X Marquis	: 2	: 26	: 239	: 26*	: :	: :
Prelude X Kanred	: 80	: 812	: 5307	: 802	: 10	: :

Pl066 X Prelude	:	2	:	23	:	160	:	23*	:	:	:	:	:
Kanred X Hard Federation:	17	:	223	:	1255	:	3	:	1	:	219	:	:
Kanred X Fulcaster	:	24	:	291	:	2190	:	4	:	3	:	269	:
										15	:	8	:
Pl068 X Fulcaster	:	2	:	26	:	221	:	20	:	5	:	1	:
										2	:	:	:
Illini Chief X Marquis	:	3	:	46	:	236	:	46	:	:	:	:	:
Illini Chief X Kanred	:	1	:	9	:	77	:	5	:	4	:	:	:
Malakof X Nittany	:	1	:	12	:	79	:	12	:	:	:	:	:

*Some resistance shown on upper leaves.

When some of these selections were inoculated the second time, after the first inoculation had failed, some resistance was found on the upper leaves. This was observed in Ridit and Kanmarq selections and also in selections of the crosses Harrod X Marquis and P1066 X Prelude.

The head selections which were not planted in the nursery in the fall of 1923 were tested in the greenhouse. These data are presented in Table III. The results obtained were very similar to those presented in Table II. This is to be expected because this material is identical with some of the material tested previously. In addition, however, tests of a large number of selections of the cross Harrod X Nebraska #23 were made. All of the 583 head selections of this cross which were tested, showed a rust class of 4, denoting complete susceptibility in the seedling stage.

With each planting of seed for greenhouse testing a few pots of parental varieties were planted as checks and these plants were inoculated with the selections and hybrids being tested. The seed used was for the most part grown in the crop improvement nursery and was bulk seed; i.e., did not come directly from individual heads or plants. A summary of the reaction of these varieties is shown in Table IV. Seventeen varieties were tested. The number of individual plants tested for each variety ranged from 57 to 1335. Fulcaster, Hard Federation, Kawvale, Marquis, and Winter King are the only varieties which showed any resistance. The resistance of Marquis was only evident when older plants (20-30 days) were inoculated, as the seedling plants of this variety were uniformly susceptible. Fulcaster contains at least two types of plants as distinguished by their reaction to form 9 of leaf rust. About 39 per cent of the Fulcaster plants are resistant, 3.9 per cent intermediate (rust class 2), and the remainder are susceptible. Approximately fourteen per cent of the Hard Federation plants were resistant, the others being susceptible or partially resistant. Some plants of Kanmarq showed an intermediate reaction. This is also true of the head selections of this variety. The author is inclined to

think the very few resistant plants in Nebraska #28, Prelude, and Shepherd Prolific are mechanical mixtures. Of the 158 plants of the Winter King variety which were tested, seven were susceptible, the others were resistant. These susceptible plants in this variety are probably mechanical mixtures or natural crosses.

Table IV.--Summary of the leaf rust reactions to physiologic form 9 of varieties used as checks in the greenhouse, 1927-28.

Variety	: Number : Number : Number of plants : of : of : : : plantings : plants : Susc. : Int. : Res.				
Farmers Trust	: 5	: 57	: 57	:	:
Fulcaster (Kans. #317)	: 18	: 231	: 132	: 9	: 90
Hard Federation	: 29	: 199	: 163	: 7	: 29
Karmarq	: 6	: 96	: 84	: 12	:
Kanred	: 89	: 1335	: 1335	:	:
Kawvale	: 3	: 56	: 1	:	: 55
Malakof	: 6	: 173	: 173	:	:
Marquis	: 18	: 215	: 197	: 11*	: 7**
Menno	: 6	: 55	: 55	:	:
Nebraska #28	: 17	: 375	: 374	:	: 1
Nittany	: 6	: 166	: 166	:	:
Prelude	: 40	: 390	: 328	:	: 2
Pl066	: 11	: 206	: 206	:	:
Ridit	: 9	: 166	: 166	:	:
Shepherd Prolific	: 6	: 107	: 106	:	: 1
Winter King	: 9	: 153	: 7	:	: 151
C. E. Leighty Sel.	: 12	: 289	: 289	:	:

*Rust class 2-3, second inoculation.

**Rust class 0-1 on upper leaves, second inoculation.

Table V presents a comparison of the greenhouse reactions expressed in rust classes and the field reaction in terms of per cent infection of the selections tested under both conditions. The maximum rust classes and the maximum rust percentage on the lower leaves were used. The rust percentages are grouped in classes of 20 per cent, beginning with 10 per cent rust. This grouping was made to simplify the table as much as possible. In a heavy rust epidemic these selections with a maximum rust of less than 50 per cent can be regarded as having some resistance.

Farmers Trust, Illini Chief, Ridit and Shepherd Prolific were susceptible in both tests. Fulcaster P.M. #11 and Kawvale were resistant in the greenhouse and also showed some resistance in the field.

Winter King, which is very resistant to form 9 in the greenhouse, showed only moderate resistance to moderate susceptibility in the field. Monno was susceptible in the greenhouse, but in the field had a very low percentage of leaf rust. The selections obtained from Dr. C. E. Leighty were all susceptible in the greenhouse and showed a wide range of rust percentages (10 to 90) in the field. All of the parents except three varieties were in the 50 per cent rust class in the field. Hard Federation had some resistant plants in the greenhouse, but was 70 per cent rusted in the

field. Kanred and Malakof, both susceptible in the greenhouse, also were in the 70 per cent rust class in the field.

Kanred X Marquis, including the named selection Kanmarq, though for the most part susceptible in the greenhouse, showed some remarkable resistance in the field. However, the few selections of this cross with a low rust class in the greenhouse were among those with the highest rust percentage in the field.

All the Prelude X Kanred selections were susceptible to form 9, with the possible exception of nine apparently intermediate selections. In the field these selections all had rust percentages of 30 to 50. Pl066 X Prelude also proved to be more resistant in the field than in the greenhouse.

In the cross Kanred X Hard Federation there was a closer relation between greenhouse and field reactions. Some marked resistance was shown by certain selections under both conditions. The same is true of Kanred X Fulcaster. The selections of Illini Chief X Marquis tested were susceptible in the greenhouse and exhibited no marked resistance in the field. Illini Chief X Kanred showed moderate resistance in the greenhouse which was also exhibited in the field. The selections of Malakof X Nittany were susceptible in the greenhouse and all but one had a high rust percentage in the field.

Table V.--Comparison of the reaction of varieties and crosses of winter wheat to leaf rust, physiologic form 9, in the greenhouse, 1927-28, and in the field, 1928.

	Greenhouse reaction						Field reaction					
	Number of selections having the maximum rust						Number of selections having a maximum rust					
Varities or crosses	class of						percentage of					
	0	1	2	3	4	seg.	10	30	50	70	90	

(a) varieties

Farmers Trust:	:	:	:	:	10:	:	:	:	:	3:	7	
Fulcaster	:	9:	:	:	:	:	:	:	:	9:	:	
R.M.11												
Illini Chief:	:	:	:	:	17:	:	:	:	:	5:	12:	
Kawvale	:	2:	:	:	:	:	:	:	2:	:	:	
Merino	:	:	:	:	10:	:	:	:	10:	:	:	
Ridit	:	:	:	:	8:	:	:	:	:	8:	:	
Shepherd	:	:	:	:	10:	:	:	:	:	2:	8	
Prolific												
Winter King	:	9:	:	:	:	:	:	:	:	8:	1:	
C.E.Leighty	:	:	:	:	26:	:	2:	1:	10:	4:	9	
Sel.												

(b) Parental varieties

Fulcaster	:	X	:	:	:	X	X	:	:	:	X	:
(Kans.#317)												
Hard Federa-	:	X	:	:	:	:	:	:	:	:	X	:
tion												
Illini Chief:	:	:	:	:	X	:	:	:	:	X	:	
Kanred	:	:	:	:	X	:	:	:	:	:	X	:
Malakof	:	:	:	:	X	:	:	:	:	:	X	:
Marquis	:	:	:	:	X	:	:	:	:	X	:	
Nittany	:	:	:	:	X	:	:	:	:	X	:	
Prelude	:	:	:	:	X	:	:	:	:	X	:	

In Table VI a summary of the greenhouse reactions of a number of hybrid selections for the years 1927-28 and 1928-29 and the field reactions for 1928 is made. No selection studied in the field had a rust class as low as 0-1, but a number of selections showed this high degree of resistance to physiologic form 9 in the greenhouse. On the other hand a large number of wheats highly susceptible to form 9 in the greenhouse were moderately resistant in the field, with a rust class of 2-3. The range of rust classes in the field is smaller than in the greenhouse.

Table VI.--Summary of the leaf rust reactions of the wheat. or

Cross	Greenhouse studies of seedling												pla
	Number of head selections												
	Rust classes												
	1927-1928						1928-1929						29
	0-1	1-2	2-3	3-4	5-6	7-8	0-1	1-2	2-3	3-4	5-6	7-8	3-4
Kanred X Marquis	:	:	:	23	:	:	:	:	:	:	:	:	23
	:	:	:	30	:	:	:	:	:	:	:	:	30
	:	:	16	:	:	:	:	:	:	:	:	:	16
Total 69	:	:	16	53	:	:	:	:	:	:	:	:	69
Kanred X Hard Federation	60	:	:	:	:	:	60	:	:	:	:	:	
	7	:	:	:	:	:	6	1	:	:	:	:	
	17	:	:	:	:	:	:	:	:	:	:	:	
	3	:	:	:	:	:	:	:	:	:	:	:	
	2	:	:	:	:	:	2	:	:	:	:	:	
	:	:	:	:	:	:	1	:	:	:	:	:	
Total 90	84	5	:	:	:	1	62	6	1	:	:	:	
Kanred X Fulcaster	131	:	:	:	:	:	131	:	:	:	:	:	
	1	:	:	:	:	:	1	:	:	:	:	:	
	47	:	:	:	:	:	:	:	:	:	:	:	
	1	:	:	:	:	:	1	:	:	:	:	:	
	2	1	:	:	:	:	:	:	:	:	:	:	
	1	:	:	:	:	:	:	:	:	:	:	:	
	:	:	:	10	:	:	:	:	:	:	:	:	
	:	:	:	:	6	:	:	:	:	:	:	:	
	:	:	:	:	4	4	:	:	:	:	:	:	
Total 204	179	4	1	10	10	136	1	:	:	:	:	:	

studied in 1923-1929.

Field studies of mature plants, 1933													
Number of head selections													
Rust classes				:	Rust percentages								
				:									
0-1:1-2:2-3:3-4:seg.				:	10:	20:	30:	40:	50:	60:	70:	80	
:	10:	13:	:	:	:	:	6:	16:	1:	:	:	:	
:	7:	22:	:	1:	:	:	1:	9:	17:	3:	:	:	
:	<u>2:</u>	<u>14:</u>	:	<u> </u> :	:	:	<u> </u> :	<u> </u> :	<u>7:</u>	<u>9:</u>	:	:	
:	19:	49:	:	1:	:	:	1:	15:	40:	13:	:	:	
:	16:	24:	18:	2:	:	:	:	14:	7:	9:	16:	8:	
:	3:	4:	:	:	:	:	2:	1:	1:	2:	1:	:	
:	7:	8:	:	2:	:	:	2:	6:	1:	7:	1:	:	
:	1:	2:	:	:	:	:	:	:	:	3:	:	:	
:	:	2:	:	:	:	:	:	:	1:	1:	:	:	
:	<u> </u> :	<u>1:</u>	<u> </u> :	<u> </u> :	:	:	<u> </u> :	<u> </u> :	<u> </u> :	<u> </u> :	<u> </u> :	<u>1</u>	
:	27:	41:	18:	4:	:	:	18:	14:	12:	29:	10:	7	
:	83:	48:	:	:	:	5:	10:	56:	42:	15:	3:	:	
:	:	1:	:	:	:	:	:	1:	:	:	:	:	
:	22:	24:	1:	:	:	:	4:	18:	18:	6:	1:	:	
:	:	1:	:	:	:	:	1:	:	:	:	:	:	
:	1:	2:	:	:	:	:	:	1:	2:	:	:	:	
:	:	1:	:	:	:	:	:	:	1:	:	:	:	
:	2:	7:	1:	:	:	:	:	9:	:	1:	:	:	
:	1:	5:	:	:	:	:	1:	4:	1:	:	:	:	
:	<u>4:</u>	<u> </u> :	<u> </u> :	<u> </u> :	<u>1:</u>	<u>2:</u>	<u>1:</u>	<u> </u> :	<u> </u> :	<u> </u> :	<u> </u> :	<u> </u> :	
:	113:	89:	2:	:	6:	16:	77:	75:	25:	5:	:	:	

Prelude X Kanred	:	:	:	2:	:	:	:	:	:	2
	:	:	:	3:	:	:	:	:	:	3
	:	:	:	<u>38</u> :	:	:	:	:	:	<u>38</u>
Total 43	:	:	:	2: 41:	:	:	:	:	:	43

*4 on lower leaves, 0-4 on upper.

:	:	2:	:	:	:	:	:	2:	:	:	:		
:	2:	:	:	1:	:	:	1:	1:	:	1:	:		
:	<u>7:</u>	<u>27:</u>	:	<u>4:</u>	:	:	<u>1:</u>	<u>1:</u>	<u>11:</u>	<u>16:</u>	<u>6:</u>	<u>1:</u>	<u>2</u>
:	9:	29:	:	5:	:	:	1:	2:	14:	16:	7:	1:	2

Selections of Kanred X Marquis, although showing some resistance on the upper leaves in the greenhouse tests in 1927-28 were all completely susceptible in the seedling stage in the greenhouse in 1928-29. Some of these hybrid selections show a high degree of resistance in the field. The increased resistance of these selections in the maturing stage is probably similar to the Marquis parent as described by Johnston and Melchers (27).

Twenty-one selections of Kanred X Hard Federation segregated for rust reaction in 1928-29 that were resistant in the greenhouse tests in 1927-28. With this exception the rust reactions of this cross for the two years agree fairly closely. Detailed data on the segregating selections are presented in Table VII. A large majority of the plants in the segregating selections tested in 1928-29 are resistant, as was the case in 1927-28. The seedling resistance in this cross comes from the Hard Federation parent as shown by the resistance of control plants of that variety inoculated with the hybrids. The segregation of these selections can be explained if the resistance of Hard Federation is dominant. The inheritance of leaf rust resistance has not been studied in detail in the earlier generations of this cross. It could therefore easily be possible that these selections are still heterozygous for rust resistance.

Table VII.--Rust behavior of segregating head selections,
Kanred X Hard Federation, tested in the green-
house.

1927 crop :		1927-28 :				1928-29 :			
improvement:Head:		Number of plants							
nursery :Tel.:		Rust class							
row No.	:No. :	0-1:	1-2:	2-3:	3-4:	0-1:	1-2:	2-3:	3-4:
1172	: 9 :	10 :	:	:	:	7 :	:	:	1
403	: 11 :	9 :	:	:	:	8 :	2 :	:	1
412	: 3 :	9 :	:	:	:	10 :	:	:	1
	: 11 :	9 :	:	:	:	20 :	:	:	1
	: 12 :	8 :	:	:	:	15 :	:	:	3
457	: 6 :	:	7 :	:	:	17 :	:	:	1
	: 7 :	:	8 :	:	:	22 :	:	:	1
	: 10 :	:	9 :	:	:	18 :	:	:	1
472	: 13 :	4 :	:	6 :	:	10 :	:	:	10
2618	: 7 :	7 :	:	:	:	19 :	:	:	6
2635	: 3 :	5 :	:	:	:	7 :	:	:	7
	: 14 :	9 :	:	:	:	25 :	:	5 :	
2644	: 11 :	7 :	:	:	:	22 :	:	:	8
2645	: 9 :	8 :	:	:	:	32 :	:	:	8
	: 10 :	4 :	:	:	:	25 :	:	:	2
	: 13 :	9 :	:	:	:	4 :	:	19 :	5
4124	: 7 :	8 :	:	:	:	60 :	:	:	1
	: 8 :	9 :	:	:	:	:	:	35 :	2
	: 10 :	9 :	:	:	:	:	:	60 :	1
4135	: 3 :	7 :	:	:	:	:	:	60 :	1
	: 11 :	10 :	:	:	:	50 :	:	:	1

The greenhouse rust reactions of the Kanred X Fulcaster selections for the two seasons correspond very closely. However there are 48 selections which segregated in 1928-29 that were resistant in the 1927-28 greenhouse tests. Johnston (26) has studied the inheritance of resistance to physiologic form 9 in this cross and concluded that resistance depends on one main factor. Resistance is carried by the Fulcaster parent and is recessive to the susceptibility of the Kanred parent. In that case we should not expect susceptible seedlings from resistant plants of this cross.

A detailed account of the segregating selections is given in Table VIII. In most cases the larger number of plants of these segregating selections are resistant. Since only a few plants could be studied in 1927-28 it may be that the number was too small to detect the segregating selections. Natural crossing in the field and mechanical mixture of seed may account for some of the apparent segregation.

There were four selections which segregated in 1927-28 and failed to segregate in 1928-29. However, in these cases, segregation was not marked in 1927-28. Only intermediate rust classes were found, with a predominating number of low rust classes. Six selections segregated in both years.

The rust behavior of the Kanred X Fulcaster crosses in the field corresponded roughly to the behavior of the same selections tested in the greenhouse. Only eighteen of the 131 resistant lines in the greenhouse had over 40 per cent rust in the field. Of the ten susceptible lines in the greenhouse all were above 40 per cent rust in the field. Most of the selections tested in the field are in the 1-2 and 2-3 rust classes. Only two selections had a rust class of 3-4.

Table VIII.--Rust behavior of segregating head selections,
 Kanred X Fulcaster tested in the greenhouse.

1927 crop		1927-28				1928-29			
Improvement:Head:		Number of plants							
nursery :Sel.:		Rust class							
row No.	No.	0-1:	1-2:	2-3:	3-4:	0-1:	1-2:	2-3:	3-4
517	:	6 :	9 :	:	:	27 :	:	:	2
	:	7 :	8 :	:	:	54 :	:	:	4
	:	13 :	9 :	:	1 :	19 :	:	:	
	:	15 :	7 :	:	:	38 :	:	:	3
541	:	7 :	9 :	:	:	11 :	:	:	9
	:	9 :	2 :	:	6 :	13 :	:	:	31
	:	10 :	9 :	:	:	32 :	:	:	2
	:	11 :	10 :	:	:	27 :	:	:	2
	:	12 :	10 :	:	:	24 :	:	:	7
	:	13 :	10 :	:	:	25 :	:	:	2
	:	14 :	10 :	:	:	29 :	:	:	2
	:	16 :	9 :	:	:	11 :	:	:	3
544	:	4 :	10 :	:	:	15 :	:	:	1
	:	6 :	8 :	:	:	33 :	:	:	2
	:	7 :	10 :	:	:	33 :	:	:	4
	:	8 :	5 :	:	:	37 :	:	:	2
	:	9 :	8 :	:	:	28 :	:	:	4
547	:	4 :	8 :	:	:	27 :	:	:	2
	:	5 :	7 :	:	:	25 :	:	:	2
	:	7 :	10 :	:	:	35 :	:	:	7
	:	9 :	10 :	:	:	45 :	:	:	9

	: 10 : 10 :	:	:	: 15 :	:	:	2
	: 11 : 8 :	:	1 :	: 15 :	:	:	
550	: 12 : 9 :	:	:	: 34 :	:	:	1
	: 13 : 9 :	:	:	: 40 :	:	:	2
553	: 9 : 9 :	:	:	: 31 :	:	8 :	1
556	: 11 : 5 :	:	:	: 35 :	:	:	5
	: 14 : 4 :	:	:	: 37 :	:	:	3
562	: 6 : 9 :	:	1 :	: 40 :	:	:	
2535	: 9 : 5 : 3 :	:	1 :	: 26 :	:	:	4
2549	: 4 : 9 :	:	:	: 40 :	:	:	10
	: 5 : 9 :	:	:	: 29 :	:	:	1
	: 6 : 9 :	:	:	: 39 :	:	:	1
	: 7 : 9 :	:	:	: 29 :	:	:	6
2552	: 8 : 9 :	:	:	: 78 :	:	:	2
	: 9 : 4 :	:	:	: 78 :	:	:	2
	: 10 : 6 :	:	:	: 79 :	:	:	1
2553	: 7 : 5 :	:	:	: 49 :	:	:	1
	: 8 : 6 :	:	:	: 59 :	:	:	1
2555	: 5 : 8 : 1 :	:	:	: 59 :	:	:	1
	: 6 : 10 :	:	:	: 99 :	:	:	1
2557	: 9 : 8 :	:	:	: 108 :	:	:	2
2561	: 4 : 9 :	:	:	: 76 :	:	:	4
	: 7 : 3 : 5 :	:	:	: 57 :	:	:	13
	: 8 : 9 :	:	:	: 23 :	:	:	2
	: 10 : 2 : 4 :	:	:	: 59 :	:	:	1

2562	:	5	:	7	:	1	:	:	:	59	:	:	:	1
	:	6	:	4	:	1	:	:	:	80	:	:	:	
	:	8	:	7	:	:	:	:	:	30	:	:	:	8
	:	12	:	9	:	:	:	:	:	56	:	:	:	4
2563	:	4	:	9	:	:	:	:	:	76	:	:	:	2
2568	:	5	:	4	:	:	:	2	:	1	:	:	:	49
4393	:	11	:	10	:	:	:	:	:	43	:	:	:	2
4384	:	7	:	6	:	:	:	:	:	39	:	:	:	1
	:	8	:	6	:	:	:	:	:	67	:	:	:	2
	:	12	:	7	:	:	:	:	:	58	:	:	:	2
4386	:	8	:	9	:	:	:	:	:	39	:	:	:	6
	:	9	:	7	:	:	:	:	:	59	:	:	:	1

The data in the preceding tables have shown the uniformity of the seedling susceptibility of selections of the Prelude X Kanred cross. Table V shows very clearly that this cross has a great deal of resistance to leaf rust under field conditions. In 1928-29 not all the available Prelude X Kanred selections were retested because of their uniform susceptibility in 1928. Those tested in 1928-29 were all found to be completely susceptible. Table II shows that a few of the selections in this cross were intermediate to form 9 in 1927-28. When the progenies of these head selections were inoculated in the greenhouse with form 9 in 1928-29, however, a uniform and highly susceptible reaction

resulted. The intermediate rust class readings of these strains in 1927-28 may have been low due to unfavorable conditions for rust infection. Evidences of field resistance are shown by the low rust classes and the large number of selections with less than 40 per cent rust.

Reactions of Selections to Other Physiologic Forms of Leaf Rust

Dr. E. B. Mains at Purdue University tested eighty-eight selections of bulk seed from the crop improvement nursery with physiologic forms 3 and 5 in 1927-28. In many cases head selection tests to form 9 were made from the same rows from which the bulk seed was taken for testing to forms 3 and 5 at Purdue. Thus these selections were tested to the three forms, 3, 5, and 9. The results of the leaf rust tests of these selections to the three forms are summarized in Table IX.

Physiologic forms 3 and 5 are prevalent in Indiana. Form 9 is the most common one in Kansas, although forms 3 and 5 and other forms are also found.

All the selections tested were susceptible to form 3 except one Kanred X Hard Federation selection and it was segregating. Kawvale and Winter King were highly susceptible to forms 3 and 5, but resistant to form 9. The Illini Chief selections were both susceptible to forms 3

and 5. Toward showed some segregation for reaction to form 5.

In the cross, Prelude X Kanred, five selections were found to be highly resistant to form 5, two resistant, one moderately susceptible, and twenty-four completely susceptible. These 24 selections were susceptible to all three forms. There was marked segregation to form 5 in a number of these selections which were uniformly susceptible to forms 3 and 9, indicating that these strains are not fixed as to their reaction to form 5 of leaf rust.

Selections in the Kanred X Fulcaster cross, some of which carry high resistance to form 9, were all susceptible to form 3. Seventeen of the 24 lines tested to form 5 were also susceptible. The remaining seven of these selections segregated in their reaction to form 5.

Table IX.--Summary of the behavior of selections and crosses of wheat tested with three physiologic forms of leaf rust.

Variety or cross	: Physiologic form 3 :				: Physiologic form 5 :				: Physiologic form 9 :			
	: Number of selections :				: Number of selections :				: Number of selections :			
	: Rust class :				: Rust class :				: Rust class :			
	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.	0-1:1-2:3:3-4:5eg.
Kawvale	:	:	1:	:	:	:	1:	:	1:	:	:	:
Illini Chief	:	:	2:	:	:	:	2:	:	:	:	:	:
Temarq	:	:	1:	:	:	:	1:	:	:	:	:	:
Winter King	:	:	1:	:	:	:	1:	:	1:	:	:	:
Prelude X Kanred	:	:	5:	:	5:	:	:	:	:	:	4:	:
and	:	:	2:	:	:	2:	:	:	:	:	2:	:
PLO66 X prelude	:	:	1:	:	:	1:	:	:	:	:	1:	:
	:	:	24:	:	:	:	24:	:	:	:	22:	:
Kanred X Hard Federation	:	:	9:	:	:	:	:	9:	:	:	7:	:
	:	:	5:	:	5:	:	:	2:	:	:	:	:
	:	:	13:	:	:	:	:	13:	:	:	:	:
	:	:	1:	:	1:	:	:	1:	:	:	:	:
Kanred X Fulcaster	:	:	17:	:	:	:	17:	:	3:	:	2:	:
and reciprocal	:	:	7:	:	:	:	7:	:	4:	:	:	:

Dr. Mains also tested 583 head selections of F_5 seedlings in the cross, Kanred X Nebraska #28, to form 5. These results are summarized in Table X.

These selections were made on the basis of time of maturity. A summary of the reactions of these selections to physiologic form 9 is given in Table III which shows that all the lines of Kanred X Nebraska #28 were completely susceptible. This is the expected behavior as both parent varieties are susceptible to form 9.

To physiologic form 5, Kanred has some resistance (rust class 2-3) and Nebraska #28 is completely susceptible (rust class 4). No conscious selection has been made for resistance to leaf rust in the earlier generations of this cross.

From Table X it would appear that susceptibility to form 5 is dominant. The large number of pure breeding lines falling in rust class 4 and the large number of segregating lines described as mostly susceptible support this conclusion. A number of genetic factors must be assumed to account for the increase in resistance of some of the hybrids over the Kanred parent. Many plants in the segregating selections had rust classes of 0 and 1, but none bred true for a rust class lower than 2.

Table X.--Summary of the leaf rust reactions of F_2 Kanred X Nebraska #28 seedlings to physiologic form 5.
(Data from Dr. E. B. Mains, Purdue University)

	Rust classes			Segregating		
Maturity class:	:	:	:	Mostly	Mostly	:
of F_2 families:	4	3	2	susceptible	resistant	Total
Early	: 237	: 31	: 26	: 143	: 32	: 469
Late	: 74	:	: 4	: 26	: 10	: 114
Total	: 311	: 31	: 30	: 169	: 42	: 583
Kanred	:	: X	: X	:	:	:
Nebraska #28	: X	:	:	:	:	:

These comparisons of rust reactions of hybrid lines to different forms of rust emphasize a number of points to be considered in studying rust resistance:

(1) A variety or selection may be uniformly susceptible to one form of leaf rust and resistant to another.

(2) A variety or even a pure line may be uniformly resistant to one form and segregating to another. Thus our conception of pure lines is very arbitrary and is necessarily restricted to the characters to which the behavior of the line is known.

(3) Leaf rust resistance must be studied with known forms. Those forms most prevalent in the area in which the wheat is to be grown should be given first consideration.

(4) The behavior of a selection of wheat to a form of rust is independent of its behavior to other forms, though

some varieties and selections are resistant to more than one form of rust.

Correlation Studies

Table XII summarizes the correlation studies that were made.

It was believed that statistical analysis of some phases of this problem would be of some interest and value. In many cases an accurate knowledge of the relations of different characters is desired and if the variables in these comparisons are correlated statistically, it is possible to obtain a definite measure of the closeness of the relationship.

For instance it is desired to correlate the field and the greenhouse reactions. However, in the greenhouse, the rust notes are taken only in rust classes while in the field the notes are usually taken in terms of percentage of rust infection. In the leaf rust nursery, 1929, detailed notes were taken on each row. The rust percentage on the upper and lower leaves, the rust class, and a description of the type of infection were recorded. These data offered an opportunity to study the relation of rust classes and rust percentages on the same material. The maximum rust percentage on lower leaves was used because it is usually higher than the rust percentage on the upper leaves. The

maximum rust class was also used in each case. Table XI shows the correlation surface of this comparison. The correlation coefficient is high, $.7828 \pm .0065$, indicating that these measures of rust reaction may be used interchangeably with a high degree of dependability. On the basis of this high correlation one would seem to be justified in correlating rust classes in the greenhouse with rust percentages in the field.

Table XI.--Correlation of the maximum rust classes and the maximum rust percentages in the leaf rust nursery, 1928.

Rust classes:	Rust percentages									
	10	20	30	40	50	60	70	80	90	Total
3-4	:	:	:	1:	7:	23:	47:	112:	228:	12: 430
2-3	:	:	:	29:	281:	213:	175:	108:	36:	: 642
1-2	:	11:	43:	151:	125:	4:	4:	3:	:	: 341
0-1	:	3:	3:	1:	:	:	:	:	:	: 7
Total:	14:	46:	182:	413:	240:	226:	223:	264:	12:	1620

$$r = .7828 \pm .0065$$

Table XII.--Correlation studies.

	Correlation of			r	PE	N
1	Maximum rust classes and maximum rust percentages in the leaf rust nursery, 1928.			.7828 ±	.0665	1620
2	Maximum rust percentages of selections in the crop improvement nursery in 1927 and 1928.			.413 ±	.069	89
3	Rust classes of hybrids to p. f. 9 in the greenhouse in 1927-28 and 1928-29, segregating selections included.			.5305 ±	.0241	406
4	Rust classes of hybrids to p.f. 9 in the greenhouse in 1927-28 and 1928-29, segregating selections omitted.			.9716 ±	.0021	327
5	Rust classes to p.f. 9 in the greenhouse in 1927-28 and rust percentages in the leaf rust nursery, 1928.			.282 ±	.012	1235
6	Rust classes of hybrids to p.f. 9 in the greenhouse in 1927-28 and rust percentages in the leaf rust nursery, 1928.			.0539 ±	.0333	406
7	Rust classes of hybrids to p.f. 9 in the greenhouse in 1927-28 and rust classes in the leaf rust nursery, 1928.			.1411 ±	.0323	406
8	Rust classes of hybrids to p.f. 9 in the greenhouse in 1928-29 and rust percentages in the leaf rust nursery, 1928.			.1843 ±	.0220	406
9	Rust classes of hybrids to p.f. 9 in the greenhouse in 1928-29 and rust classes in the leaf rust nursery, 1928.			.116 ±	.033	406

- | | | |
|--|--------------|------|
| 10 :Rust classes of selections to p.f. 5 in the greenhouse in: 1927-28 at Purdue University and rust percentages in the crop improvement nursery, Manhattan, 1927. | : .070 \pm | : 92 |
| 11 :Rust classes of selections to p.f. 5 in the greenhouse in: 1927-28 at Purdue University and rust percentages in the crop improvement nursery, Manhattan, 1928. | : .072 \pm | : 89 |

* p.f. refers to physiologic form of leaf rust.

The second correlation study was made to see if the field rust percentages of the selections which were sent to Dr. Kains were correlated for the years 1927 and 1928. The number of selections was rather small, but a significant correlation was found, $.413 \pm .069$. This value of r indicates that the reactions of the varieties tested tend to remain about the same in two consecutive years. The third and fourth correlations are comparisons of the greenhouse rust classes in 1927-28 and 1928-29. The figures were taken from Table VI. In one case the value for r was $.5305 \pm .0241$. However, in making up the correlation table the segregating selections were included and were classed above the type 4 (completely susceptible) reactions. This placing of the segregating classes is quite arbitrary and may be subject to criticism. The inclusion of 79 segregating selections in the correlation table naturally lowered the value of r . Another correlation table was made up in which the segregating lines were omitted. The very high value of r , $.9716 \pm .0021$, indicates the very high probability of the selections reacting the same in successive years if tested to the same form of rust, provided there is no segregation.

The fifth and sixth correlations are between rust classes in the greenhouse, 1927-28, and the field rust percentage, 1928. These values are much lower. One of

them ($.282 \pm .012$) is statistically significant, but is not of much practical value. The extremely low value of $.0539 \pm .0333$ for the sixth correlation is due to the relatively large number of segregating selections included in the greenhouse studies. The seventh correlation is very much like the preceding ones except that the rust classes in the field are used instead of the rust percentages. The value of r , $.1411 \pm .0328$, is low and of doubtful statistical significance. Here again the large number of segregating lines tends to reduce the value of r . The eighth correlation is very similar to the sixth except in this case the greenhouse rust classes, 1923-29, are correlated with rust percentages in the field in 1928. The value of r , $.1346 \pm .0220$, is low, but is of statistical significance. The ninth correlation is between the greenhouse rust classes in 1923-29 and field rust classes in 1928. The value of r , $.116 \pm .033$, is low and has neither statistical nor practical significance.

The inter-annual correlation (No. 2) indicates that the rust behavior in the field from year to year is significantly correlated. The rust behavior in the greenhouse from year to year is very highly correlated when a single form of rust and homozygous strains of wheat are used. The correlations between the rust behavior of seedlings to form 9 in the greenhouse and of mature plants in the field

where form 9 is prevalent are low. Some of them are statistically significant, but none of them are of much practical value.

Correlations 10 and 11 are between greenhouse reactions of the selections tested to form 5 at Purdue University and the field reactions at Manhattan in 1927 and 1928, respectively. Very low and statistically insignificant values of r were obtained, indicating that rust reactions to physiologic form 5 are independent of the field reactions of the selections at Manhattan, Kansas.

No correlation studies involving form 3 were made, because all the selections except one were susceptible to this form.

Leaf Rust Reaction of Hybrids in Different Stages of Growth

This study was thought desirable because of the peculiar resistance shown by some of the hybrids in 1927-28 when older plants were inoculated. About 250 representative samples from each of the crosses, Kanred X Marquis and Prelude X Kanred, were used. As many pedigree selections were represented as possible. Seedling inoculation was done by hand to insure infection. All the hybrids as well as the parental strains were susceptible in the seedling stage.

The data comparing the rust reactions of hybrids and parental varieties in different stages of growth are presented in Table XIII. Many of the plants tested in the seedling stage died before the second inoculation was made. Only those plants which were inoculated in both stages of growth are included in the summary presented in Table XIII. All of the plants of both crosses and parental varieties had a rust class of 4 when inoculated in the seedling stage. Due to the failure to secure infection on some of the plants in the seedling stage rust notes could not be taken. This accounts for the smaller number reported in the seedling stage than in the heading stage.

This study indicates:

1. The three parental varieties, Kanred, Marquis and Prelude exhibit some resistance in the heading stage--the stage in which the rust notes are taken in the field.

2. This type of behavior is inherited by the hybrid offspring in both crosses, Kanred X Marquis and Prelude X Kanred.

3. Some hybrids are more resistant in the heading stage than either parent, which indicates that a number of factors govern the reaction of hybrids in the heading stage. These factors cannot be studied by means of inoculations made only in the seedling stage because the visible effects of these genetic factors are not exhibited till later

in the life of the host plant.

One family in the cross Kanred X Marquis from row #2753 of the 1927 crop improvement nursery showed remarkable resistance in the heading stage. Representatives from three head selection progenies from this row were tested. Only one plant in this family was moderately susceptible (rust class 2-3) and the other nine plants were highly resistant (rust class 0-1).

Table XIII.--Comparison of reactions of hybrids and parents to leaf rust physiologic form 9 in different stages of growth.

Variety or Cross	Number of plants inoculated									
	Seedling stage:					Heading stage				
	Lower leaves:	Upper leaves:	Rust class			Lower leaves	Upper leaves	Rust class		
	4	4	0-1	1-2	2-3	3-4	0-1	1-2	2-3	3-4
Kanred X Marquis	:	:	22	:	:	:	21	1	:	:
	:	:	:	20	:	:	18	2	:	:
	:	:	:	:	53	:	24	20	9	:
Total 184	167	164	22	20	53	89	24	19	31	15
						69	87	42	40	13
Prelude X Kanred	:	:	7	:	:	:	7	:	:	:
	:	:	:	5	:	:	2	3	:	:
	:	:	:	:	13	:	6	4	3	:
Total 102	92	98	7	5	13	77	13	9	19	36
						77	23	16	22	36
Kanred	:	:	:	1	:	:	:	:	:	1
	:	:	:	:	1	:	:	:	1	:
	:	:	:	:	:	5	:	:	2	3
Total 7	7	7	:	1	1	5	:	:	3	4
Marquis	:	:	:	1	2	:	3	:	:	:
Total 3	3	3	:	1	2	:	3	:	:	:
Prelude	:	:	:	:	1	:	:	:	1	:
	:	:	:	:	:	2	:	:	1	1
Total 3	3	3	:	1	1	2	:	:	2	1

SUMMARY

1. A survey was made of the leaf rust percentages of varieties grown in the leaf rust and crop improvement nurseries since 1917. Data were obtained in all seasons when the amount of leaf rust present was sufficient to provide for reliable estimates. Very few of these varieties have maintained their resistance in the field during this period of years. Those which have low rust percentages in the years tested are: Four selections of Fulcaster, R.N. 4, 11, 21 and Fulhard; Fultz, CI 5308; Hungarian, CI 3299-1M; Indiana Swamp, Kans. #62; Kawvale, CI 8180; Mediterranean, CI 3332; Menno, Kans. #496; Oro, CI 8220; Prelude, Kans. #352-2; Purkof, Kans. #2612; Tormarq, CI 6936; Turkey, Kans. #2473; and Winter King, CI 3546. Kanred, P1066 and P1068 though showing considerable resistance in the field prior to 1922 have since then been more or less susceptible.

2. A large number of seedling plants from head selections in varieties and crosses showing leaf rust resistance in the field in 1927 were tested to physiologic form 9 in the greenhouse, 1927-28. Fulcaster R.N. #11, Kawvale and Winter King showed resistance in the seedling stage. Resistance was also found in the crosses Kanred X Hard Federation and Kanred X Fulcaster. The other hybrids tested were

all susceptible. However, when inoculated when twenty to thirty days old, some plants showed resistance on the upper leaves. A few Prelude X Kanred and Kanred X Marquis selections behaved in this manner.

3. A number of parental varieties were used as checks in the greenhouse studies. Resistance was found in Kawvale and Winter King. Hard Federation and Fulcaster contained both resistant and susceptible types. All other varieties were susceptible.

4. Comparisons were made of the greenhouse reaction of seedlings to form 9 in 1927-28 and the field rust percentages of mature plants in 1928. In general the selections susceptible to form 9 in the greenhouse had higher rust percentages in the field than the types resistant to form 9 in the seedling stage. However, many exceptions were noted.

5. Greenhouse tests of lines grown in the leaf rust nursery, 1928, were made in 1928-29. The hybrids used in this study were; Kanred X Marquis, Kanred X Hard Federation, Kanred X Fulcaster and Prelude X Kanred. The material tested in 1928-29 behaved very similarly to that tested in 1927-28. However a number of selections were found to be segregating for rust resistance in 1928-29, which were resistant the previous year. These reactions were explained as segregations of the heterozygous though phenotypically

resistant plants in 1927-28. If the resistance of the Hard Federation parent is considered dominant this situation is easily explained because no selection on the basis of rust resistance has been made previously. In the cross Kanred X Fulcaster the presence of segregating lines is believed to be due to mechanical mixtures of seed and to natural crossing in the field. The number of susceptible plants in the segregating selections was usually very small.

6. Bulk seed from a number of selections was tested to physiologic forms 3 and 5 in 1927-28. A summary of this study, together with comparisons with the reactions of head selections from the same rows, shows that (a) the three physiologic forms are very distinct in their host relationships, (b) all the selections tested except one were susceptible to form 3 and (c) a number of selections uniformly susceptible to form 9 were segregating for reaction to form 5.

7. A number of correlation studies were made from which the following generalizations were drawn:

(a) In the field the rust classes (0, 1, 2, 3, 4) and the rust percentages (0 to 100) are both reliable measures of rust resistance and susceptibility.

(b) The rust classes of a group of selections tested as seedlings in the greenhouse are usually significantly correlated with the rust reactions of the same selections

in the field. The value for r in these studies ranged from .05 to .28. Low values for r were due to segregation in the greenhouse material.

(c) When homozygous seedlings were inoculated with physiologic form 9, the rust classes were very highly correlated with the rust classes the following year ($r = .97$).

(d) The field reaction at Manhattan is independent of the greenhouse reaction to physiologic form 5 at LaFayette, Indiana, ($r = -.05$ and $.006$).

8. A number of selections taken at random in the crosses, Kanred X Marquis and Prelude X Kanred, were tested to physiologic form 9 in the greenhouse in 1928-29 at different stages of growth. All these selections were susceptible in the seedling stage. The mortality of the plants was high due to poor greenhouse conditions. Rust inoculations were made in the heading stage. The conclusion drawn from this study is that some hybrid plants which are completely susceptible in the seedling stage show varying degrees of resistance in the heading stage.

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Plate I. Scale used for estimating rust percentages in the nursery.

SCALE FOR ESTIMATING RUST.

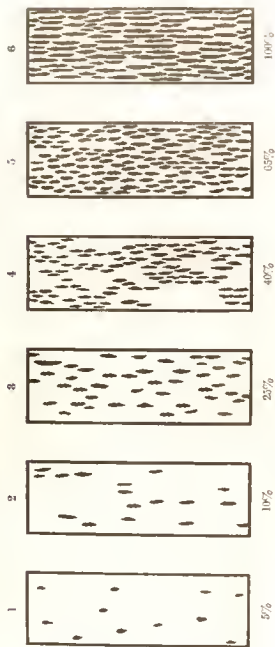


Diagram showing six degrees of rustiness which may be used in estimating the percentage of rust infection on leaf or stem. The smallest spots represent rust, and the figures represent approximately the rust percentages. This figure (No. 6 in the diagram) represents 55% of actual surface and is arbitrarily selected as 100%. Other percentages are indicated by the figures.

This scale is only of replication. A number of leaves are gathered from the top or flat at random, and a number of plants carefully examined for stem rust, these are compared with the diagrams and the proper figures recorded in the notebook.

The plus or minus sign may be used to indicate a slightly greater or less amount of rust than the nearest figure.

When the plant is severely infected, the figures are recorded, they do provide a useful systematic method for recording rust infection, and will more intelligibly represent the facts than will figures showing rustiness.

(Continued)

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Plate II. Rust reactions of certain hybrid selections when inoculated with physiologic form 9 in the greenhouse.

The two groups at the left are leaves from Kanred X Bard Federation seedlings showing a typical 0 reaction.

The group at the right are leaves from Prelude X Kanred seedlings showing a typical 4 reaction.

