STUDIES OF PHYSIOLOGIC RACES OF THE LEAF RUST IN WHEAT (*PUCCINIA RUBIGO-VERA TRITICI*) IN MEXICO

by

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INTRODUCTION

A study of the physiologic races of leaf rust in wheat, Puccinia rubigo-vera tritici (Erikss. & Henn.) Carleton, in Mexico was made for two special reasons. The first objective was to determine the physiologic races present in Mexico so that the plant breeders could develop new varieties which would be resistant to the prevalent races. This in turn would increase the wheat production in Mexico. The second objective was to compare the prevalence and distribution of the physiologic races in Mexico in relation to the light it might throw on the northward movement of the races in the United States and the overwintering of the leaf rust of wheat in Mexico.

The investigations reported in this paper represent three phases of work. First, a complete analysis of the collections received from Mexico in the spring and fall of 1950 was made. A second phase consisted of compiling and analyzing the data obtained from the collections received during the period 1944 to 1949 and combining them with the 1950 data. The third phase consisted of comparisons between the important races of leaf rust in Mexico and the United States for each year that Mexican collections were received. This also comprised comparisons between the important races of leaf rust in Mexico and the United States for all collections received during the 7-year period from 1944 to 1950. The purpose of these comparisons was to determine, if possible, the interchange of leaf rust spores between Mexico and the United States.

History of Wheat Production and the Importance of Leaf Rust in Mexico

The raising of wheat in Mexico is localized in an area approximately 6,000 to 9,000 feet above sea-level and comprises some 50,000 square miles of the great central plateau. The principal wheat producing states are Guanajuato, Coahuila, Puebla, Sonora, Mexico, Queretara, Hidalgo and Chihuahua. In 1920 the average yield was less than one bushel per capita. This was due to the low-quality mongrel wheat sown and the severe damage caused by the wheat rusts. Wheat rusts have cost Mexico millions of dollars annually. In certain regions the rust epidemic has at times been so severe that the farmers had to burn their crops. Since the rusts flourish in the moist summer weather, the Mexican farmer, up to the present, has always been obliged to grow his wheat in the winter. During that season, however, it is so dry that irrigation is needed in order to insure a crop.

In February of 1943, the Mexican Agricultural Program was initiated as a joint undertaking of the Rockefeller Foundation and the Mexican Department of Agriculture, the goal being to improve the productivity of Mexico's agriculture (3). The Rockefeller Foundation sent agricultural specialists into Mexico to assist in the effort to increase the national food production and make that country more nearly self-sufficient in grain production.

Borlaug and Rupert (1) reported in 1948 that leaf rust of wheat caused by Puccinia rubigo-vera tritici has become an increasingly important factor in wheat production in Mexico. This is due to the many varieties that were introduced into Mexico because of their known stem rust resistance, all of which are highly susceptible to leaf rust under Mexican conditions. They

also state that there is at least one physiologic race of leaf rust not commonly found elsewhere that is highly pathogenic to a wide range of wheat varieties, including the durums. In 1949 about 9 percent of the cultivated land of Mexico was in wheat. This 1,375,000 acres produced 16,599,000 bushels of wheat. However, only 100,000 acres or one-eighth of the total acreage was growing wheat which was resistant to leaf rust.

Interchange of Rust Spores Between Mexico and the United States

Stakman et. al. (6) reported in 1940 that stem rust, Puccinia gramis tritici, Eriks. and Henn., can persist throughout the year in southern Mexico because there is an overlap of crop seasons. Most of the wheat is grown during the winter, but a small amount is grown during the summer. Therefore, early sown fields of summer wheat may become infected from late-maturing fields of winter wheat in the spring, or early summer and early-sown fields of winter wheat may become infected from late-maturing fields of summer wheat. After a study of stem rust races in Mexico and the United States, they concluded that there has been little seasonal interchange of stem rust between southern Mexico on one hand and northeastern Mexico and the United States on the other. For example, races 49 and 56 had not been found in southern Mexico despite their abundance in the United States and northeastern Mexico. Race 56 was reported in the United States several years before being found in Mexico. They state that there is no implication that there never is an interchange of

inoculum of rust between northeastern Mexico and the United States. At least in some seasons an interchange is indicated by studies of air movements, results of spore trapping, chronological developments of rust, and the tendency toward variations in prevalence of certain physiologic races.

In order for the leaf rust of wheat, Puccinia rubigo-vera tritici, to be carried from Mexico to the United States, the spores would have to pass through and over several natural barriers in Mexico and the United States. Some of these natural barriers in Mexico are the eastern spur of the Sierra Madre in Tamaulipas and Nuevo Leon, which have an elevation of 6,000 feet. Furthermore, the valley of Mexico, where most of the wheat is grown, is surrounded by a range of mountains 15,000 feet in elevation.

Another factor affecting the movement of rust spores between Mexico and the United States is wind movement. The prevailing winds in Mexico blow from the north from September to March. This is during the wheat growing season and most of the rust spores would be carried southward into the Gulf of Mexico. Most Mexican wheat is harvested in March so only a few spores would be present to be carried northward with the prevailing spring winds which are from the south from March to September. If some of these spores were carried into Texas it is doubtful that they could become established early enough to start the northward movement of spores in the United States.

In the Rio Grande valley often referred to as "The Winter Garden of Texas," there is very little wheat grown. This is one

of the most important areas in the United States in which the rust spores can overwinter in abundance. In the past this area grew wheat for winter pasture, but in recent years farmers have been growing oats for winter pasture. This greatly reduces the source of spores of the wheat rusts which would serve as an inoculum for the vast wheat acreages of the states farther north.

Another natural barrier is the Edwards Plateau of Texas which is 315 miles south of Amarillo. It is an area 801 miles in length and 773 miles in width. This area covers four Texas counties and is approximately the size of the State of Tennessee. It is a rocky, broken country with a very shallow top soil, which is rich in the proper minerals and covered with buffalo grass, scrub oak, mesquite and juniper. Very little of this land is cultivated and there is no wheat grown on which the urediospores could become established if they were carried by wind from Mexico.

A review of the direction of the prevailing winds and the natural barriers would seem to indicate that Mexico is not the overwintering grounds of the prevalent races of leaf rust found in the United States.

MATERIALS AND METHODS

The first collections of the leaf rust from Mexico were received and analyzed as early as 1935. However, only two collections were analyzed and this is not considered enough to show the prevalence of races in Mexico or the movement of rust spores. No collections were received in 1936 and 1937; only one was received

in 1938, and three in 1939. None of these is sufficient to throw much light on the problems under study.

The first large group was not received until 1944 when H. A. Rodenhiser sent a group of 14 collections to Manhattan for analysis. Since then the collections have been sent by N. E. Borlaug, Plant Pathologist, J. S. Niederhauser, Associate Plant Pathologist, and several Mexican collaborators. Rust collections were made in the field at various points in Mexico during the spring and fall. Each year urediospores on green leaves were collected. These leaves were pressed and placed in glassine envelopes and sent to the Manhattan rust laboratory. When the collections were received they were stored in the refrigerator at 45° F. until they were cultured for determination of the physiologic races. To establish cultures the spores were scraped from the leaves with a small moistened spatulate needle and placed in a drop of water on a glass slide, from which they were transferred to the leaves of four of the differential varieties of Triticum vulgare. These varieties are Malakof (C.I. 4898), Webster (C.I. 3780), Loros (C.I. 3779), and Democrat (C.I. 3384). Transfers were made to the first seedling leaves of the above named varieties by first moistening the leaves by rubbing them between the thumb and forefinger which had been moistened with distilled water. The spatula was then dipped into the spore-suspension on the slide and rubbed over the moistened leaves leaving spores spread over the leaf surface.

The inoculated seedlings were then placed in small moist chambers. These moist chambers are small galvanized-iron cylin-

ders which were seated in sand. The chambers and sand were moistened with tap water. The plants were then placed in the chambers and the leaves moistened by spraying with tap water. A pane of greenhouse glass was placed on top of the chambers, thus maintaining a high relative humidity inside the moist chamber, a condition favoring spore germination and infection. The plants were removed from the moist chambers after a twenty-four hour period and placed in pans on the greenhouse benches. The resulting infections were allowed a ten-day period to reach full development before readings were made.

After 10 days well-isolated individual pustules were selected from each one of the four varieties and transferred to Cheyenne wheat seedlings growing in four-inch pots. Spores from each pustule were carefully collected on a moistened spatula and transferred to the Cheyenne seedlings. After each transfer the spatula was heated over an alcohol flame to destroy the remaining spores and the hands were washed under running tap water and dried before making the next transfer. The Cheyenne seedlings were placed in ordinary wash tubs and sprayed with tap water. A large pane of glass was placed over the tub and the seedlings were left for 24 hours. At the end of that time the pots were removed and placed on greenhouse benches. Lantern globes were placed over the plants in each pot in order to keep each culture pure. This method established pure-line cultures originating from single uredia.

These cultures were allowed to develop for a ten-day period after which each was transferred to a set of differential vari-

eties in order to identify the physiologic race represented by each culture. Only five of the eight differential varieties were used in these studies since the shorter series saved space and, in most cases, gave the desired results. Three of the eight differential varieties are unreliable since they often give varying or indeterminate reactions under the environmental conditions at Manhattan and, therefore, may obscure the physiologic races involved. In that respect Newton and Johnson (5) have clearly shown that some of the differential hosts used in the isolation of physiologic races of leaf rust have entirely different reactions under different conditions of temperature and light. For example, Carina (C.I. 3756) and Hussar (C.I. 4843) tend to show resistance under low temperatures and susceptibility under high temperatures. They also often give indeterminate reactions which are difficult to classify. These two varieties, therefore, were not used. Mediterranean (C.I. 3332) was not used since it usually gives the same type of reaction as Democrat (C.I. 3384).

The five differential varieties were used, Malakof (C.I. 4898), Brevit (C.I. 3778), Webster (C.I. 3780), Loros (C.I. 3779) and Democrat (C.I. 3384). If there was any doubt as to the correct race, the pure culture was transferred to the full set of differentials which included the above five varieties plus Carina, Mediterranean, and Hussar.

As soon as the pure-line cultures were fully developed they were transferred to sets of differential varieties. The five differentials were placed in the moist chambers and sprayed with tap water as described earlier. The seedlings then were inocu-

lated by brushing the leaves with a pure culture which was at least 10 days old. Extreme care was taken in brushing the pure culture on the differentials to prevent contamination. The infected Cheyenne seedlings were brushed in a circular motion making sure that all of the differentials were contacted by the rust on the Cheyenne seedlings. This precaution was necessary in order to obtain infection on all varieties so that accurate readings could be obtained.

When the differentials were removed from the moist chamber they were placed in pans on the greenhouse benches and left for 10 days to permit full development of rust infections. The readings were made following the classifications set up by Mains and Jackson (4) which show the types of infections designated by the Arabic numerals 0, 1, 2, 3, and 4, with 0 representing the greatest resistance and 4 the highest susceptibility. Numerals 0, 1, and 2 represent resistant types of infection and 3 and 4 represent susceptible types. The International Register of Physiologic Races of the Leaf Rust of Wheat (Puccinia rubigo-vera tritici) and the Condensed Dichotomous Key for the Identification of Physiologic Races of Puccinia rubigo-vera tritici were used as guides in determining the physiologic race of leaf rust represented by each pure-line culture.

When the readings were made, if there were any signs of a mixture, two or three single pustules were isolated from at least two of the differential varieties to establish purification. These in turn were placed on the differential varieties. This procedure was repeated until there was no mixture

evident. A mixture of races could be determined if one variety showed both resistant and susceptible type infections at the same time.

EXPERIMENTAL RESULTS

Physiologic Races of Puccinia rubigo-vera tritici in Mexico During the Period 1944 to 1950

During the period 1935 through 1950, 29 physiologic races of leaf rust have been isolated from collections received from Mexico. There is evidence that some of the physiologic races may be merely variants of other races arising from differences in temperature or other environmental conditions as reported by Newton and Johnson (5). For example Chester (2) by using five differentials grouped the following races together: Race 5 5, 52; 9 9, 10, 19, 20, 31; 15 15, 2, 25; 37 37, 43, 50, 64, 110, 128, 58 58, 3, 12, 44; 105 105, 6, 103, 126. Since only 5 differential varieties were used in the present studies some very similar races are grouped. After the races are grouped into similar race groups there were 11 distinct physiologic groups of leaf rust of wheat, Puccinia rubigo-vera tritici, found in Mexico from 1944 to 1950. These 11 races were isolated from 147 collections and include races 5, 9, 11, 15, 37, 58, 68, 92, 93, 105, and 126. These are distinctly different on the basis of the 5 differential varieties used and will be designated as physiologic races in the forthcoming discussion.

As stated earlier only a few collections were received from Mexico prior to 1944. These comprised two collections in 1935,

one in 1938 and three in 1939. From these 6 collections physiologic races 5, 9, and 38 were isolated once each and races 11 and 26 three times each. These data are too meager to do more than indicate that races 11 and 26 were important races in Mexico at that time. The first sizable group of collections consisted of 14 collections made in three states in Northern Mexico in 1944. The results of the analysis of these collections are shown in Table 1.

The data in Table 1 show that the 14 collections yielded 6 physiologic races. The most abundant race was physiologic race 11 which represented 48 percent of all isolates. Race 11 was also isolated from 13 of the 14 collections showing that it was widely distributed as well as abundant. Race 37 was the next important race comprising 20.6 percent of all isolates. During the same year in the United States race 11 was isolated only 5 times from 331 isolates representing 143 collections, showing that it was an unimportant race North of the Rio Grande river that year. The most important races in the United States were 126, 9, and 15. The last two races were found in Mexico, but in small amounts. Race 15 made up 6.8 percent of the total isolates, while race 9 made up 10.3 percent of the total isolates made from the Mexican collections. In the United States during the same year race 9 made up 29.2 percent of all isolates, while race 15 represented 9.6 percent. This evidence indicates that Mexico probably was not the overwintering ground for the races of leaf rust prevalent in the United States in 1944.

No collections were received in 1945 from Mexico and only

Table 1. Physiologic races of Puccinia rubigo-vera tritici isolated from collections made in field and nursery sowings in Mexico during 1944 and analyzed at Manhattan, Kansas, in the winter of 1944-45.

State	Number of collections	Physiologic races and number of times isolated							Total number of isolates
		5	9	11	15	37	58	105	
Coahuila	9	1	1	8	1	5			16
Guanajuato	2			4	1	1		2	8
Queretara	3		2	2			1		5
Total	15	1	3	14	2	6	1	2	29
Percent of total isolates		3.4	10.3	48.2	6.8	20.6	3.4	6.8	

one collection was received in 1946. From this collection races 9 and 15 were isolated once each.

Beginning with 1947 a very satisfactory number of collections was received each year through 1950. Each year the number of collections was large enough and widely enough distributed to give a very definite picture of the prevalence and distribution of physiologic races of leaf rust in the principal wheat-growing states in Mexico. In 1947 a total of 22 collections from 5 states was analyzed. The results of the analysis of these collections are shown in Table 2.

The data in Table 2 show that 9 physiologic races were identified among 101 isolates. Physiologic race 11 was by far the important race representing 62.9 percent of all isolates. Furthermore, race 11 was isolated from 21 of the 22 collections. Races 9, 37, and 58 were the next important races, occurring in about equal amounts. However, race 9 made up only 8.3 percent of all isolates and races 37 and 58 each represented only 8.2 percent of the total isolates. Races 126 and 5 each represented only 4.1 percent of all races isolated. During the same year in the United States 305 isolates from 87 collections were analyzed. Race 11 was isolated 21 times representing 6.9 percent of all isolates. The important races isolated in the United States were 9 and 5, each making up 20.3 percent of all isolates. Race 15 represented 16.7 percent and race 126 represented 13.4 percent of all isolates made from the United States collections for 1947. Thus, while race 11 was a very important race in Mexico in 1947, it was of minor importance in the United States,

Table 2. Physiologic races of Puccinia rubigo-vera tritici isolated from collections made in the field and in nursery sowings in Mexico during 1947 and analyzed at Manhattan, Kansas in the winter of 1947-48.

State	Principal locality	Number of collections	Physiologic races and number of times isolated										Total number of isolates
			5	9	11	15	37	58	92	105	126		
Sonora	Cd. Obregon	5	1	3	12		2	5			2		25
Coahuila	Nadadores	1	1	1			1						3
Queretara	Queretara	1			1	2	1	2					6
Guanajuato	Iropuato	6		1	22					1			24
Mexico	Chapingo	9	2	4	28	1	4	1	1		2		43
Total		22	4	9	63	3	8	8	1	1	4		101
Percent of total isolates			4.1	8.3	62.9	2.2	8.2	8.2	1.0	1.0	4.1		

while races 5, 9, 15, and 58 which were important in the United States were much less important in Mexico. Therefore, a comparison of the collections analyzed from Mexico and the United States in 1947 indicates that Mexico was not the overwintering ground for the races of leaf rust which were prevalent in the United States during the 1947 growing season.

During 1948 collections again were made in 5 states in Mexico and sent to Manhattan for physiologic race analyses. A total of 26 collections was received. These yielded 72 isolates from which 10 physiologic races were isolated. The data obtained are summarized in Table 3.

The data from Table 3 show that physiologic race 11 again was the important race in Mexico representing 58 percent of all isolates made from the 1948 collections. Race 9 was the next important race but only represented 9.4 percent of all isolates. The third important race from the 1948 collections had not been isolated in the previous years. This was physiologic race 93 representing 8.0 percent of all isolates. Another physiologic race was isolated this year which had not been isolated in past years. This was physiologic race 68 which was isolated once from collections received from Chapingo, near Mexico City. Races 15, 58, and 105 each represented 5.4 percent of all isolates from the 1948 collections.

An analysis of the isolations made in the United States in the 1948 season shows that race 11 which was the most important one in Mexico was of minor importance. Physiologic race 11 was isolated 38 times from 502 isolates representing 174 collections

Table 3. Physiologic races of Puccinia rubigo-vera tritici isolated from collections made in the field and nursery sowings in Mexico during 1948 and analyzed at Manhattan, Kansas, in the winter of 1948-49.

State	Principal locality	Number of collections	Physiologic races and number of times isolated										Total number of isolates
			5	9	11	15	37	58	68	92	93	105	
Sonora	Cd. Obregon Ixmiquilpan	9	1	1	14	2		3				4	25
Hidalgo	Lagunilla	5			5			1		1			7
Queretara	El Colorado Salamanco	1	1		1		1						3
Guanajuato	Celoya	9		5	19	2	1						33
Mexico	Chapingo	2		1	2				1		6		4
Total		26	2	7	41	4	2	4	1	1	6	4	72
Percent of total isolates			2.7	9.4	58.0	5.4	2.7	5.4	1.3	1.3	8.0	5.4	

and made up only 7.8 percent of all isolates. The important races in the United States in 1948 were 126, 58, and 5. Race 126 represented 19.1 percent; race 58, 18.3 percent; and race 5, 16.5 percent of all isolates. Race 126 was not isolated in Mexico in 1948, race 58 represented only 5.4 percent and race 5 represented only 2.8 percent of all isolates made from the 1948 Mexican collections. This evidence indicates that Mexico probably was not the overwintering ground for the races of leaf rust prevalent in the United States in 1948.

In 1949 the number of collections received from Mexico was increased over those received in preceding years. Forty collections were analyzed and eight physiologic races were identified from 66 isolates. These were races 11, 5, 105, 93, 9, 15, 37, and 58 in their order of importance and prevalence. The data obtained are summarized in Table 4.

The data in Table 4 show that race 11 represented 47.0 percent of all isolates made from the 1949 collections and was still the most important race in Mexico. This year for the first time physiologic race 5 established itself as an important race. It was isolated 15 times from 3 of the 5 states and represented 22.7 percent of all isolations. However, race 11 was still by far the most important race, being isolated more than twice as many times as race 5. Race 105 was also an important race in Mexico in 1949 as it was isolated from all states and represented 21.2 percent of all isolates. Race 93 was the fourth most important race representing 3.0 percent of the isolations. Races 9, 15, and 58 each represented only 1.5 percent of the total

Table 4. Physiologic races of Puccinia rubigo-vera tritici isolated from collections made in the field and nursery sowings in Mexico during 1949 and analyzed at Manhattan, Kansas, in the winter of 1949-50.

State	Principal locality	Number of collections	Physiologic races and number of times isolated								Total number of isolates
			5	9	11	15	37	58	93	105	
Sonora	Cd. Obregon	6	2		5	1			1	2	11
Coahuila	Torreon	6			5			1		1	7
Queretara	Queretara	12			12				1	5	18
Guanajuato	Iropuato	6	4		2					5	11
Mexico	Chapingo	10	9	1	7		1			1	19
Total		40	15	1	31	1	1	1	2	14	66
Percent of total isolates			22.7	1.5	47.0	1.5	1.5	1.5	3.0	21.2	

isolates and were distinctly minor races. In contrast to the data for Mexico, race 11 was only isolated 3 times from 807 isolates representing 308 collections made in the United States in 1949. It, therefore, represented only 3.0 percent of all isolations made from the United States collections as compared to 47 percent of all isolations made from the Mexican collections. In the United States the important races were 5, 9, 126, and 105. Race 5 represented 28.8 percent and race 9 made up 21.9 percent of all isolations. Races 126 and 105 were important races representing 16.5 percent and 13.1 percent, respectively, of the isolations made from the 1949 collections. Race 126 was not isolated in Mexico and race 9 represented only 1.5 percent of all isolations.

As stated earlier race 5 became an important race in Mexico for the first time in 1949. However, race 5 was one of the important races in the United States as early as 1946. This would seem to indicate that the United States might be the source of some of the physiologic races of rust found in Mexico. This is in line with information obtained earlier with stem rust wherein it was shown that some races were important in the United States before they became important in Mexico.

The data presented in the first four tables and the discussions pertaining to them were compiled and prepared by the writer from voluminous data accumulated in earlier years. The data for Table 5 were prepared from analyses of Mexican collections for 1950 cultured by the writer. They are presented in

Table 5. Detailed data on the physiologic races of Puccinia rubigo-vera tritici isolated from collections made on wheat in various parts of Mexico in the spring and fall of 1950 and studied at Manhattan, Kansas, in the winter of 1950-51.

State	Localities	Varieties	Number of collections	Date collected	Physiologic races and number of times isolated						Total number of isolates
					5	9	11	15	93	105	
Sonora	Cd. Obregon	Bread Wheat	6	4/20/50	9	1	1			1	12
				4/ 4/50	2	1	3		1		
Coahuila	Saltillo	Bread Wheat		4/ 6/50	1	1	1		1		
				4/20/50		1	1				
		Candeal		4/12/50		1	1	1		1	
	Hermanas	Candeal	16	4/11/50	2					2	45
	Allende	Mentana		4/13/50	1		1				
	General Zepoda	Candeal		4/12/50							
	Las Estoncias	Candeal		4/11/50	2	1		1			
	Ramas Orizpe	Bread Wheat		4/ 6/50	2	1	3	2	1		
	Piedres Negras	Candeal		4/11/50	3			1		1	
		Mentana		4/11/50		2				1	
	Zoragoza	Candeal		4/11/50						1	
Tamaulipas	Reynosa	Bread Wheat	1	4/ 4/50	2						2
		Durum	5	10/26/50	1		4	1	2		20
Guanajuato	Iropuato	On volunteer		10/26/50	3		6	1	2		
Mexico	Chapingo	(Morroquis x Newthatch) x Newthatch	18	10/23/50	3		3	1			52
		Mayo 48			1		1				
		T. sphaerococcum				1	2	3			
		Warden Leap								1	
		Kenya			2		2				
		T. khapli					2				
		Kenya x Rockefeller Foundation					1	1	1		
		San Miquel			1						
		Carleton			1		1		1		
		Kenya x Aquilera			1		2	1			
		(Mentana x Kenya) x Mentana			4		3				
		T. persicum					1	1	1		
		T. vernal					1				
		Kentana 48			1		1				
		Newthatch x R.F. 304			2		2				
		T. piramidale					2				

detail, as well as summarized (Table 6) to illustrate the amount of material handled and the information recorded pertaining to it. The information is presented here, instead of earlier in the paper, because it keeps the information in chronological order by years.

Forty-six collections were received from Mexico in 1950 and studied in detail. A complete analysis is presented in Table 5 showing the varieties of wheat involved, date collected, physiologic races isolated, and the state and localities from which each collection was received. Twenty-three of the collections were made in the spring and an additional 23 collections were made the following fall. The spring collections were made in the northern states of Sonora, Coahuila and Tamaulipas. The fall collections were made from wheat growing in the states of Guanajuato and Mexico which are in the valley of Mexico. Races 5, 11, and 15 were isolated in about equal numbers in both spring and fall collections. Races 9 and 105 were isolated from most of the spring collections but only once each from the fall collections.

The data on the physiologic races isolated from collections received from Mexico in 1950 are summarized in Table 6. Six physiologic races were identified from 131 isolations representing 46 collections. For the first time race 11 was not the most important race isolated. Race 5 was the most abundant race making up 33.5 percent of the isolates compared to 32.8 percent for race 11. The next important races were 15

Table 6. Summary of data on physiologic races of Puccinia rubigo-vera tritici isolated from collections made in the field and nursery sowings in Mexico during 1950 and analyzed at Manhattan, Kansas in the winter of 1950-51.

State	Principal locality	Number of collections	Physiologic races and number of times isolated: 5	9	11	15	93	105	Total number of isolates
Sonora	Cd. Obregon	6	9	1	1			1	12
Coahuila	Saltillo	16	13	8	10	5	3	6	45
Guanajuato	Iropuato	5	4		10	2	4		20
Mexico	Chapingo	18	16	1	22	6	6	1	52
Tamaulipas	Reynosa	1	2						2
Total		46	44	10	43	13	13	8	131
Percent of total isolates			33.5	7.6	32.8	9.9	9.9	6.1	

and 93 each comprising 9.9 percent of all isolates, while race 9 represented 7.6 percent of the isolates made from the 1950 collections.

In the United States 807 isolates were obtained from 283 collections made in 1950. Race 11 was found only 12 times and accounted for only 1.5 percent of the isolations in the United States. The important races isolated in the United States were races 5, 9, 126, and 58, in the order of importance. Race 5 was the most important race representing 29.3 percent of all isolates. Races 9 and 126 each represented 18.0 percent of the isolations and races 105 and 58 each made up 8.8 percent of the isolations for the 1950 season. It is interesting to note that race 11 appeared but once in the isolates from the State of Sonora during the 1950 season. In the past years race 11 was usually found in abundance on the collections received from Sonora.

The data on the physiologic races isolated from the collections made in Mexico for the 7 year period from 1944 to 1950 are summarized in Table 7. During this period 379 isolates representing 147 collections yielded a total of 11 races. The lowest number of races identified in any one year was 6 in 1950, and the highest was 10 in 1948. Although 11 races were isolated during this period, race 68 was isolated only once, race 92 twice, and race 126 was isolated only four times. This leaves 8 races which represented more than 1 percent of the total number of isolates and, therefore, appear to be of considerable importance.

Table 7. Physiologic races of Puccinia rubigo-vera tritici isolated from collections made in the field and nursery sowings in Mexico from 1944 to 1950 inclusive.

State	Total collections	Physiologic races and number of times isolated											Total number of isolates
		5	9	11	15	37	58	68	92	93	105	126	
Sonora	26	13	3	34	3	2	8			1	7	2	73
Coahuila	31	17	10	23	7	6	1			3	7		74
Guanajuato	28	8	6	57	5	1				10	8		95
Queretara	17	1	2	16	1	2	3			1			26
Tamaulipas	1	2											2
Mexico, F.D.	39	20	7	51	7	4	1	1	1	6	2	2	102
Hidalgo	5			5			1		1				7
Total	147	61	28	186	23	15	14	1	2	21	4	4	379
Percent of total isolates		16.1	7.3	49.0	6.0	3.9	3.6	0.2	0.5	5.5	1.0	1.0	

Although the data show that 11 races were isolated from seven states in Mexico during the 7-year period, it should be noted that there were only 5 collections from Hidalgo and only 1 collection from the State of Tamaulipas. The largest number of collections were received from the State of Mexico and this was the only state where all 11 races were isolated at least once. Race 68 was isolated only in the State of Mexico and race 92 was isolated in Mexico and Hidalgo. Race 11 was isolated from all of the states except Tamaulipas. Its absence there was probably due to the small number of collections received from that state. Race 126 was isolated only in Sonora and the State of Mexico, being isolated twice from collections made in each state.

Despite the fact that 11 races were isolated, the most common was physiologic race 11 which comprised 49 percent of the total number of isolates and appeared in abundance in all years and in all states except Tamaulipas.

Physiologic race 5 was the second most common, comprising 16.1 percent of all isolates. It was not abundant in the early years but increased in importance in the last two years and was found in all states except Hidalgo.

Physiologic race 105, ranking third in abundance, comprised 6.3 percent of all isolates, but varied in abundance from year to year and was not important except during the 1949 season.

Physiologic race 93 comprised 5.5 percent of all isolates made in Mexico during the 7-year period. This race was not

isolated until 1948 but appeared each year thereafter. It was isolated from collections from all states except Tamaulipas and Hidalgo but reached its greatest abundance in the state of Guanajuato.

Physiologic Races of the Leaf Rust of Wheat in the United States as Related to the Occurrence of the Same Races in Mexico

The final phase of the studies made during the course of the investigations reported in this season consisted of a compilation of the physiologic races isolated from collections made in the United States and comparison of the data with similar data obtained from Mexican collections for the same years. The period 1944 to 1950 inclusive was chosen for that purpose. It was desired to learn which were the most abundant and widely distributed races in each country and what relation, if any, there was between them. It also was important to learn whether there was any relation between the prevalence of certain races in Mexico and the prevalence of the same races in the various important wheat-growing areas in the United States. It was particularly important to determine whether races that were abundant in Mexico also were abundant in the great wheat-growing area of central United States directly north. For that reason the prevalence of the races in the individual states of the hard red winter and hard red spring wheat-growing areas of the United States are shown in Table 8, while only area totals shown for the less important Atlantic and Gulf, Great

Table 8. Physiologic races of Puccinia rubigo-vera tritici isolated from collections made in field and nursery sowings in the United States from 1944 to 1950 inclusive.

Areas & states	Total collections	Physiologic races and number of times isolated										Total number of isolates
		5	9	11	15	21	37	58	93	105	126	
Atlantic & Gulf	195	105	56	4	48	6	6	68	47	72	59	471
Great Lakes	90	46	18	7	30		10	73		25	48	257
Pacific Coast	44	7	12	65	3		10	21		1	7	126
Great Plains												
N. Dakota (Mandan)	23	16	37	4	18		24	12		18	23	177
Colorado	43	43	35		4		1	8		2	5	73
North Central												
Nebraska	65	38	92		13	1	2	17		9	29	181
Iowa	74	44	60		23		16	15		27	40	225
S. Dakota	32	12	13	3	9		9	11	1	5	11	74
N. Dakota (Fargo)	14	5	5		2		4	2		6	5	29
Minnesota	46	33	19	1	23		17	6		21	78	129
South Central												
Texas	125	86	22	4	21		19	20	1	23	43	309
Oklahoma	79	47	57		18		12	9		12	42	197
Kansas	285	202	224	2	56	16	27	49	2	75	128	781
Missouri	35	13	16		11	1	6	11		8	31	97
Arkansas	15	16	4		2		2	3	1	3	15	46
Kentucky	12	9	2		2	1		6	1	2	8	31
Total	1,117	722	742	90	283	25	165	331	53	302	572	3,272
Percent of total isolates		22.0	22.7	2.7	8.6	.76	5.0	10.1	1.6	9.2	17.5	

Lakes and Pacific coast areas.

Table 8 summarizes by sections and states the physiologic races isolated in the United States for the 7-year period from 1944 to 1950. These data are shown in graphic form compared with similar data for Mexico in Fig. 1. During that period 3272 isolations were made and analyzed from 1177 collections representing the six areas. The most important races isolated from collections made in the United States were physiologic races 9 and 5, which occurred in almost equal abundance. They were followed by races 126, 58, 105, 15, and 37, in the order named.

Races 68 and 92 which were isolated in Mexico were not isolated from the collections analyzed in the United States during the 7-year period.

Physiologic race 93 has been isolated once from the North Central area, 47 times from the Gulf area and 5 times from the South Central area. Thus, race 93 was of some importance in southeastern United States but not elsewhere and represented only 1.6 percent of all isolations made in the United States for the 7-year period.

It is particularly important to compare carefully the prevalence of physiologic race 11 in the United States and Mexico since the studies already discussed have shown that race to be the most abundant one in Mexico. While Table 7 shows that race 11 represented 49 percent of all isolates made from Mexican collections during the period 1944-1950 inclusive, Table 8 shows that it comprised only 2.7 percent of all isolates made

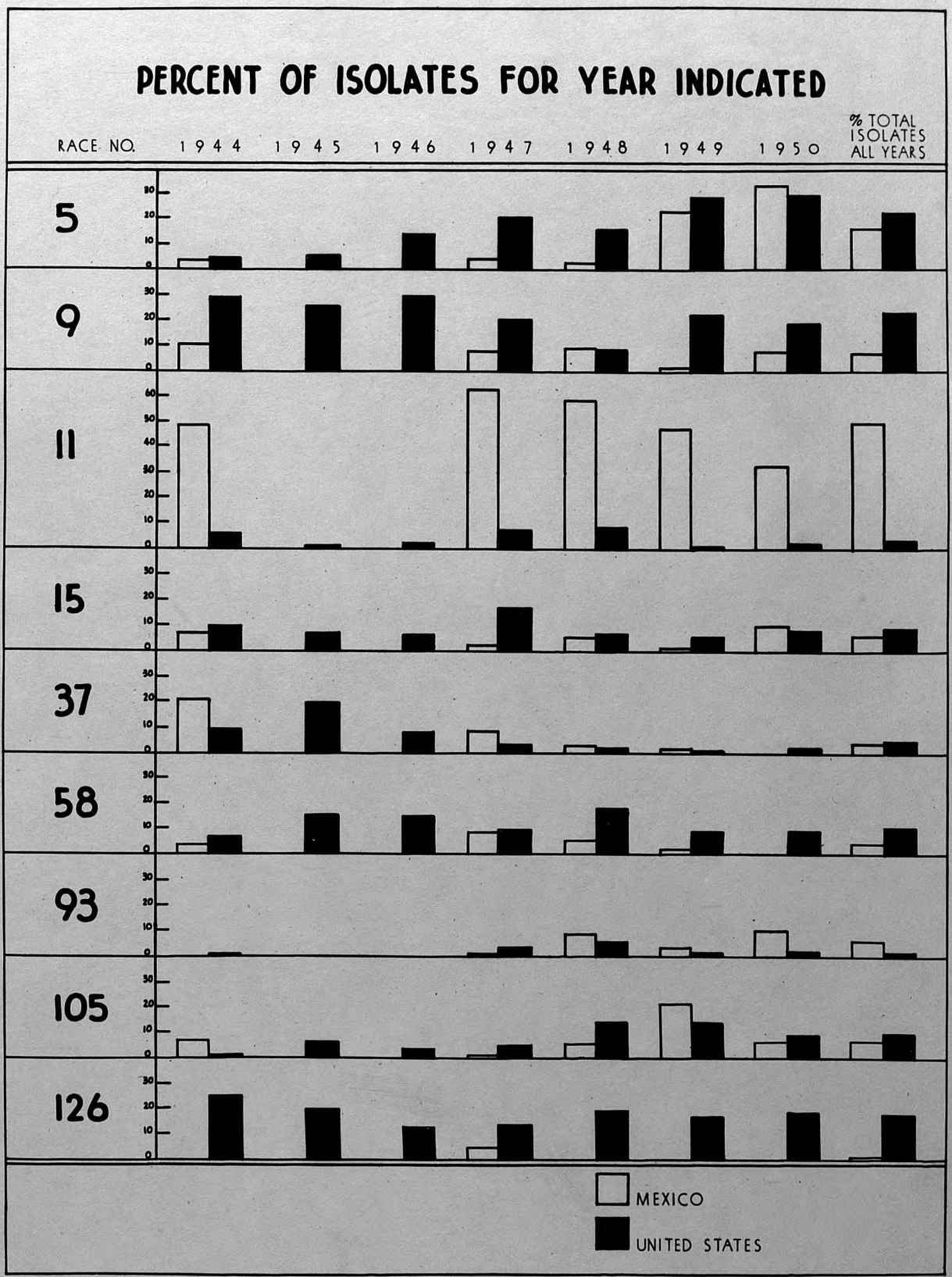

Fig. 1: A comparison of the physiologic races of leaf rust in Mexico and the United States for the 7-year period from 1944-50.

from United States collections during the same period. This comparison is clearly shown in Fig. 1. The only area in the United States where race 11 was important was the Pacific coast where it represented 51.6 percent of all isolations. It has been the most abundant race in the collections received from California, Oregon, Washington and Idaho. Apparently the Rocky Mountains form a rather effective barrier to the eastward movement of rust spores since race 11 has appeared only in insignificant amounts east of the mountains, as shown by Table 8. There also is good evidence that race 11 has not moved in abundance out of Mexico into the hard red winter and hard spring areas of the United States since it was found in no greater abundance in Texas than it was in North Dakota. It represented only 1.3 percent of all isolations made from Texas collections and 1.9 percent of all isolates made from North Dakota collections. On the basis of these observations there seems little to support the theory that physiologic races of the leaf rust of wheat overwinter on wheat in Mexico and move from there into the wheat-growing areas of the United States. As a matter of fact, there is more evidence to support the theory that the reverse is true. For example race 5 has been a very important race in central United States since 1946 but not until 1949 did it become important in Mexico and in 1950 it was slightly more abundant than race 11.

SUMMARY

Data on the physiologic races of Puccinia rubigo-vera tritici isolated from collections made on wheat in Mexico during the period 1935 to 1950, inclusive, were compiled and studied in detail in an effort to determine the prevalence of races in Mexico and their relation to the prevalence of races in the United States. The Mexican collections made in 1950 were cultured and analyzed by the writer as a part of this study.

Physiologic race 11 was the most outstanding race in Mexico during the period covered by these studies. It was the only race that represents approximately 50 percent of all isolates made for any one race for the 7-year period. Race 11 was never of major importance in the United States as it accounted for only 2.7 percent of all isolates for the 7-year period.

Physiologic race 5 was second in importance for the 7-year period but was unimportant in the earlier years. However, race 5 increased from 2.7 percent of all isolates in 1948 to 33.5 percent in 1950. This shows a marked increase in abundance in the last two years. Race 5 represented 14 percent of all isolates made in the United States as early as 1946 and is steadily increasing. This evidence would suggest that physiologic race 5 moved from the United States into Mexico.

Physiologic races 9, 126, and 58, which are important races in the United States, were of minor importance in Mexico. Race 126 which represented 17.5 percent of all isolations made in the United States for the 7-year period represented only 1 per-

cent of the isolates made in Mexico for the same period.

The only race which was about the same in abundance in both countries was race 15, which represented 6 percent of all isolates made in Mexico and 8.6 percent of all isolates made in the United States for the 7-year period.

Physiologic race 93 was the only race beside race 11 which was more abundant in Mexico than in the United States. This race represented 5.5 percent of the isolates made in Mexico, compared to 1.6 percent of the isolates made in the United States for the 7-year period.

A complete analysis of the collections made in Mexico and compared with the collections made in the United States for the 7-year period from 1944 to 1950 showed that, while the evidence is not conclusive, Mexico is not the overwintering ground for the physiologic races of leaf rust that are prevalent in the United States. It seems from the evidence presented that the United States is the source of inoculum for some of the races of rust found in Mexico.

This evidence can be supported by the fact that stem rust race 56 of wheat was isolated in the United States before being found in Mexico. Also stem rust race 7 of oats was reported in the United States several years before it was isolated in Mexico. At the present the new and prevalent stem rust of wheat 15B has gained importance in the United States but as yet has not been reported from Mexico.

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A STUDY OF PHYSIOLOGIC RACES OF THE LEAF RUST OF WHEAT (*PUCCINIA RUBIGO-VERA TRITICI*) IN MEXICO

by

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An analysis of the physiologic races of leaf rust in Mexico was made for two reasons. First, to determine the races of leaf rust in Mexico so that resistant varieties could be developed. Secondly, to determine whether Mexico has been the overwintering ground for the races of leaf rust which are prevalent in the United States. A complete analysis of the collections received from Mexico in 1950 were made by the writer and in addition the data from collections received from 1944 to 1949 were analyzed and combined with the 1950 data.

From 1944 through 1950, 379 isolates representing 147 collections from seven states of Mexico were analyzed. The following races in order of prevalence were isolated: 11, 5, 9, 105, 15, 93, 37, 58, 126, 92, and 68. Race 11 was by far the important one, comprising 49 percent of all isolates, while race 126, a very important one in the United States, represented only 1.0 percent of all isolates in Mexico.

Data for similar studies made in the United States during the same period revealed that 3272 isolates representing 1177 collections were analyzed. Races 9, 5, 126, 58, 105, 15, 37, 11, 93, and 21 were the important races isolated in the order named. Race 126 represented 17.5 percent of all isolates in the United States while race 11, the most abundant one in Mexico, represented only 2.9 percent of all isolates in the United States from 1944 to 1950.

While the evidence is not conclusive, it does indicate that Mexico is not the principal overwintering ground for the races of leaf rusts which are prevalent in the United States. In several

cases races were prevalent in the United States before they were isolated from Mexican collections, indicating that rust moves from the United States into Mexico rather than from Mexico into the United States.