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Title: PHYSIOLOGIC RACES OF STRIPE RUST (PUCCINIA STRIIFORMIS WEST.) OF WHEAT (TRITICUM AESTIVUM VILL.) IN THE PACIFIC NORTHWEST DURING 1971 AND 1972

Abstract approved: Redacted for privacy
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The virulence of 44 isolates of stripe rust (Puccinia striiformis West.) from 33 collections made during 1971 and 1972 were characterized on two sets of differential varieties. The varieties in the "Oregon" set were: Cappelle Desprez, Chinese 166, Dippes Triumph, Druchamp, Etiole de Choisy, Flamingo, Gaines, Golden, Ibis, Leda, Michigan Amber, Moro, Omar, Rubis, Suwon 92 x Omar^4, and Yamhill. The varieties in the "U. S." set were: Lemhi, Chinese 166, Heines VII, Moro, Suwon 92 x Omar^4, Druchamp and Riebesel 47-51. Races were named using a modification of the recently proposed system of decanery numbers. Each race was designated by two values, e.g., OR 106-362, making a dual system of values. The first number (106) represents varieties showing 3 and 4 infection types and the second (362) those with 2, 3 and 4 infection types. Based on this dual

system, 19 physiologic races of stripe rust were identified from the 33 collections.

Certain races named by the dual system may be closely related and show a shift in virulence over time. Based on the number of races identified in the Pacific Northwest, from a relatively few collections, a great diversity of races in time and space occurred. More than half of the collections were different races.

Two major wheat varieties grown in the Pacific Northwest, Gaines and Nugaines, supported 11 out of the 19 races identified. However, only one race, OR 110-110 (Moro race), was associated with Moro wheat while the other varieties supported two or more races. The Pacific Northwest was partitioned into five distinct wheat growing areas based on geographic plus ecological differences. Race OR 106-106 was the most widely distributed race and was found in all areas except the Upper Columbia Basin. The widespread distribution of this race may be related to its ability to attack a wide range of commercially grown Pacific Northwest wheat varieties.

All of the wheat growing areas had one or more races in common, even though 11 of the 19 races were specific for one of the five designated wheat growing areas. The distribution pattern of stripe rust races, therefore, in the Pacific Northwest is neither area specific nor variety dependent. No race has predominated in the population since 1964. However, there was evidence for a seasonal shift in the race make-up of the stripe rust population.

In view of the extensive genetic diversity in the stripe rust population in the Pacific Northwest, there is a potential for stripe rust epidemics on old and new wheat varieties. This danger can be reduced by growing varieties with different genetic backgrounds and by maintaining genetic diversity in the varieties of wheat.

Physiologic Races of Stripe Rust (*Puccinia striiformis* West.) of Wheat (*Triticum aestivum* Vill.) in the Pacific Northwest During 1971 and 1972

by

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Typed by Susie Kozlik for Cevdet Dutlu

TO MY MOTHER

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PHYSIOLOGIC RACES OF STRIPE RUST (PUCCINIA STRIIFORMIS WEST.) OF WHEAT (TRITICUM AESTIVUM VILL.) IN THE PACIFIC NORTHWEST DURING 1971 AND 1972

Introduction

Stripe rust (*Puccinia striiformis* West.) is widely distributed throughout the world and is an important rust disease of wheat in the Pacific Northwest. The Pacific Northwest epidemic of stripe rust in 1961 caused estimated losses of about 15 and 30 million dollars, respectively, in Oregon (Shaner and Powelson, 1971) and Washington (Hendrix, 1964).

This epidemic and others during the early sixties were favored by the extensive planting of a single susceptible variety, Omar, which comprised 60 to 70 percent of the winter wheat acreage. Environmental conditions, as favorable as they were in 1961, have occurred in other years, but releases of resistant varieties such as Gaines, Nugaines, Moro, Yamhill, Hyslop, Paha, Wanser, McCall, Luke, Coulee and others prevented serious losses.

Gaines and Nugaines are susceptible to stripe rust in the seedling stage but show a mature plant resistance, which is conditioned by high temperatures. These two varieties accounted for approximately 65 percent of winter wheat production in the Pacific Northwest in 1971. The other new varieties have good resistance to stripe rust and have been widely accepted in areas of adaptation. This diversity of wheat germ plasm in the Pacific Northwest should prevent the build-up of a single dominant race of stripe rust.

Stripe rust has high vertical mutability and new races evolve quickly (Manners, 1950; Fuchs, 1960; Zadoks, 1961; Sharp, 1962, 1965; Macer and Doling, 1966; Purdy and Allan, 1966; Beaver and Powelson, 1969; Little and Manners, 1969a, b; Fuchs, 1967; Beaver, 1969, 1972). Thus, there is a recognized potential danger from stripe rust to the extensive wheat culture of the Pacific Northwest and it is important that more be learned about the physiologic races in this area. The objectives of this study were to: (1) obtain information concerning occurrence and distribution of races of stripe rust of wheat in the Pacific Northwest, and (2) add to the chronological history of change in the stripe rust population.

REVIEW OF LITERATURE

Stripe rust (P. striiformis West.) was first recognized and described by Eriksson and Henning in 1890 and was identified in the United States by the visiting Danish plant pathologist F. Kølpin Ravn in 1915 (Humphrey and Johnson, 1916).

Stripe rust of wheat occurs on all continents except Australia and is favored by cool-humid climates (Zadoks, 1961). Distribution in the United States is confined mostly to the Pacific Northwest (Oregon, Washington and northeastern Idaho), western Montana, and northern California (Hendrix, 1964).

The fungus is polymorphic and as far as is known has a hemiform of life cycle where only the uredial, telial and sporidial stages are present. The sporidia do not infect (Eriksson and Henning, 1896; Gäumann, 1959) any known host. The life cycle is confined to the uredial stage and can perpetuate itself on both wild and cultivated Gramineae (Hungerford, 1923; Humphrey, Hungerford and Johnson, 1924).

Identification of Physiologic Races

Existence of physiologic races in P. striiformis West. was first established by Allison and Isenbeck (1930) with the aid of ten differential varieties. Later, in 1932 Gassner and Straib established a system for identification of physiologic races of *P. striiformis* based on 11 differential varieties of wheat which are still widely used. These differentials consisted of the following varieties: Blé rouge d'Ecosse, Strubes Dickkopf, Webster C. I. 3780, Holzapfels Früh, Vilmorin 23, Heines Kolben, Carstens Dickkopf V, Spalding's Prolific, Chinese 166 and Prolifique barbu.

Manners (1950) identified 13 races from Great Britain by using the standard set of Gassner and Straib's differentials plus the variety Wilma. In 1961, Zadoks simplified the infection-scale used by Gassner and Straib and used additional varieties for race identification. In tests at Wageningen only four differentials of Gassner and Straib (Vilmorin 23, Heines Kolben, Carstens V and Chinese 166) were found to be reliable. The others gave varying responses under different environmental conditions. Based on these four differentials, 16 races were identified. Fuchs also (1960, 1965) re-evaluated the Gassner and Straib's differentials and found that some of the differentials were unreliable. She combined some of the previously described races into unified groups where differences between the races were not very clear.

The problem of stripe rust race identification and naming was discussed at a meeting of European workers in May, 1970 (Johnson *et al.*, 1972). They proposed that all races be identified on a world list of differential varieties and any regional sets that may be developed (Johnson et al., 1972). The world set contains seven varieties: Suwon 92 x Omar, Strubes Dickkopf, Moro, Vilmorin 23, Heines Kolben, Lee and Chinese 166. The European set of differential varieties has been tested (Sharp, 1965; Line, 1969) but has not worked effectively to differentiate the predominate races of *P. striiformis* in the United States. Race identification in the U. S. has been made on various sets of differential wheat varieties (Bever, 1934; Sharp, 1962; Purdy and Allan, 1966; Beaver and Powelson, 1969; Beaver, 1969, 1972). Unfortunately, they are all different and the results cannot be compared.

Line et al. (1970), in an attempt to standardize the race identification in the U. S., developed a set of differential varieties which they thought best represented the range of virulence within the United States. This set consisted of Lemhi, Chinese 166, Heines VII, Moro, Suwon 92 x Omar, Druchamp and Riebesel 47-51.

Decanery System of Race Naming

In the past, the naming of races has been arbitrary, e.g.; 6, 20, 20A, 3/55, 60, W16, Heines V11, OR 8-68, and without biological significance or systematic nomenclature (Gassner and Straib, 1932; Manners, 1950; Fuchs, 1960, 1965, 1967; Zadoks, 1961; Macer and Doling, 1966; Beaver, 1969). In an attempt to solve this problem, Green (1965), Line et al. (1970) and Loegering and Browder (1971) suggested that information on the susceptibility of differential varieties be incorporated into an avirulent/virulent formula for stem rust, stripe rust and leaf rust, respectively. In this system, sequential numbers were assigned to differential varieties of wheat in a systematic manner and a slash (/) was used to separate numbers that represented varieties on which the race was avirulent from those on which the race was virulent. The numbers for the varieties were listed from left to right in order of increasing susceptibility. Addition of further differential varieties would be simple in this system. Difficulties arise, however. First the name is designated by a long list of numbers, and second numbers may not occur in the same sequence making comparisons difficult, e.g., 1, 5, 7, 4/3, 2, 6 and 7, 5, 4, 1/6, 3, 2 would be considered the same race.

The system of naming rust races, recently proposed by Habgood (1970) and adopted for naming races of stripe rust by Johnson _et al._ (1972), readily portrays, in a single number, information concerning the virulence of races on differential varieties. This recently proposed system used the characteristic of binary notation (Habgood, 1970) and permits the concise naming of physiologic races by indicating against which differential varieties the race is virulent. In this system to designate a race, a selected set of differential varieties are first arranged in a fixed numerical order. These varieties are assigned numerical values in a binary notation and the derived numbers are converted to decanery values for each variety. The summed number of decanery values for varieties on which the race is virulent is then used as the name of the race. Thus, the spectrum of virulence of a given race can be simply obtained from its designation and no other combination of differentials will have this value. The following example illustrates how the system works for a given race (X):

Differential variety	G	F	E	D	C	B	A
Numerical order	7	6	5	4	3	2	1
Binary notation	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Decanery value	64	32	16	8	4	2	1
Reaction of race X	R	S	R	S	R	R	R
Designation of race X			32 + 8 = 40				

Geographic Distribution and Frequency of Occurrence of Races of Stripe Rust

Since the initial work of Gassner and Straib on physiologic specialization of stripe rust, more than 60 races have been described from various countries (Fuchs, 1965). However, the exact number of races is not certain because various workers have used different sets of differential varieties.

Using the Gassner and Straib differentials plus the variety Wilma, Manners (1950) reported 13 races in Britain. Among these races, 6 and 8 were widespread in England whereas 2 and 3 were restricted to the south. Fuchs (1960) used the Gassner and Straib differentials and described 12 races from the following countries: Germany, Norway, Sweden, Denmark, Belgium, Great Britain, Ireland, France, Switzerland, Spain, Egypt, Israel, Afghanistan and Iran.

More recently, Stubbs (1973) reported 32 different races from 17 different countries based on the reactions on the world set plus the European set of differential varieties and named them according to the newly developed system of race identification and nomenclature (Johnson, et al., 1972). Of these 32 races, three races, 6 E 16, 40 E 0, and 0 E 0, were the most widely distributed, but each one was found only in four countries one or three times each. Most of the collections consisted of different races.

Zadoks (1961) used Fuch's (1960) data to compute the relative frequency of some races for a few northwest European countries. The race spectra of the different countries were rather similar but the frequency of occurrence varied. Race W 12 was common in the Netherlands, while races W 14, W 18, W 4 dominated in Germany and races W 16, W 8, W 8, W 13 in Belgium, Spain, France and Switzerland, respectively.

The Rothwell Perdix race (race 60) first reported in England in the early spring of 1966 (Macer and Doling, 1966) was also found in the Netherlands in the late spring (Fuchs, 1967) and was more aggressive than any other known races. In 1955, Heines VII race was first reported from the Netherlands, but subsequently extended all over northeast Europe (Hassebrauk, 1959).

Little is known of the distribution of stripe rust races in the United States. Bever (1934) reported two distinct physiologic forms of stripe rust from Montana and Idaho. Sharp (1962, 1965) identified a race of stripe rust in Montana which was different than those previously reported from North America (Bever, 1934; Newton and Johnson, 1936) and Europe (Fuchs, 1960). Sharp and Volin (1970) reported obtaining 11 isolates from collections made in Washington, Idaho, Oregon, Utah and Montana with different genes for virulence. Beaver (1969, 1972) described 12 races from collections that were made in Oregon, Washington and Idaho. Tollenaar and Houston (1967) considered all the stripe rust collections they made in California to be the same race. The Suwon 92 race was collected in 1963, 1964 and 1965 at several locations in Washington, Oregon and Utah (Purdy and Allan, 1966). The Moro race was tested on a number of varieties and found to be virulent on 26 different varieties, with several varieties highly resistant (Beaver and Powelson, 1969). These two races were characterized by their virulence on Suwon 92 and Moro wheat (Purdy and Allan, 1966) (Beaver and Powelson, 1969), respectively. They both have special importance because they are virulent on these exotic and indigenous sources of resistant germ plasm used in Pacific Northwest breeding programs as well as other parts of the world.

Unfortunately, no comparisons on the reported races could be made because each individual worker in the United States has used his own set of differential varieties.

MATERIALS AND METHODS

Uredospores of P. striiformis West. were collected from infected wheat, triticale and grass plants in 1971 and 1972. Collections were made from various locations in Oregon, Washington and northern Idaho (Table 1).

The fresh sporulating leaves collected in the field were placed in envelopes and allowed to air dry or they were placed in a test tube containing 2 to 3 ml. of a 60 pmm benzimidazole solution where they could continue to sporulate. If the samples were to be stored before isolation, the dried leaves were cut into small pieces and placed in one ml ampules, flamed, sealed and stored in liquid nitrogen. Rust collections and cultures were increased by inoculating uredospores on a mixture of Gaines and Omar wheat seedlings. The seedlings were grown in vermiculite and sub-irrigated with Hoagland's solution. Single spore isolates were obtained by inoculating individual Gaines wheat seedlings with a single spore by the dry twist method (Fleischmann, Khair and Dinoor, 1966). Only 2 to 12 percent of the inoculations were successful using this technique. The inoculum resulting from the single spore cultures was then increased on a mixture of Gaines and Omar wheat. Uredospores were harvested with a cyclon spore collector (Tervet and Cherry, 1950) and stored in one ml ampules at 3 C and 50 percent relative humidity. Inoculum that was

Table 1. Pacific Northwest stripe rust collections and isolates evaluated in 1971 and 1972.

Collection No.	Town	Host	Date	Isolate[1]
1	Corvallis, Oregon	Druchamp wheat	May, 1971	SW-95-3
2	Morrow, Oregon	Nugaines wheat	May, 1971	W-96
2	Morrow, Oregon	Nugaines wheat	May, 1971	SW-96-1
3	Pullman, Washington	Wheat	June, 1971	W-97
4	Spillman, Washington	Wheat	June, 1971	SW-98-1
5	Corvallis, Oregon	Triticale	June, 1971	ST-99-1
6	Crabtree, Oregon	Nugaines wheat	June, 1971	SW-101-1
7	Corvallis, Oregon	Nugaines wheat	June, 1971	SW-102-1
8	Pendleton, Oregon	Moro wheat	June, 1971	SW-104-1
9	Wasco, Oregon	Wheat	June, 1971	SW-105-1
10	Almira, Washington	Nugaines wheat	July, 1971	SW-107-1
11	Moscow, Idaho	Luke wheat	July, 1971	SW-108-1
12	Wilbur, Washington	Nugaines wheat	July, 1971	SW-110-1
13	Moscow, Idaho	Michigan Amber wheat	July, 1971	SPW-111-1
14	Aurora, Oregon	Gaines wheat	July, 1971	W-112
14	Aurora, Oregon	Gaines wheat	July, 1971	SW-112-1
15	Lind, Washington	PI 167822/101 hybrid wheat	July, 1971	SW-116-1
16	Harrington, Washington	Omar wheat	July, 1971	SW-118-1
17	Moscow, Idaho	Wanser wheat	July, 1971	SW-120-1
18	Pullman, Washington	Yamhill wheat	July, 1971	SW-123-1
19	Hillsboro, Oregon	Gaines wheat	July, 1971	W-125
19	Hillsboro, Oregon	Gaines wheat	July, 1971	SW-125-1
19	Hillsboro, Oregon	Gaines wheat	July, 1971	SW-125-2
20	Holdman, Oregon	Wanser wheat	April, 1972	SW-126-1
21	Moro, Oregon	Gaines wheat	April, 1972	W-127

Table 1. Continued.

Collection No.	Town	Host	Date	Isolate[1]
22	Corvallis, Oregon	Orin wheat	April, 1972	SW-128-1
23	Aurora, Oregon	Wheat	May, 1972	SW-129-1
24	Aurora, Oregon	Wheat	May, 1972	SW-130-1
25	Mission, Oregon	Gaines wheat	May, 1972	W-131
25	Mission, Oregon	Gaines wheat	May, 1972	SW-131-1
25	Mission, Oregon	Gaines wheat	May, 1972	SW-131-2
25	Mission, Oregon	Gaines wheat	May, 1972	SW-131-3
25	Mission, Oregon	Gaines wheat	May, 1972	SW-131-4
25	Mission, Oregon	Gaines wheat	May, 1972	SW-131-5
25	Mission, Oregon	Gaines wheat	May, 1972	SW-131-6
26	Moro, Oregon	Omar wheat	May, 1972	W-132
26	Moro, Oregon	Omar wheat	May, 1972	SPW-132-1
27	Moro, Oregon	Gaines wheat	May, 1972	SPW-134-1
28	Adams, Oregon	<u>Elymus</u> <u>condensatus</u>	June, 1972	SE-135-1
29	Dufur, Oregon	Omar wheat	June, 1972	SW-136-1
30	Madras, Oregon	Anzer wheat	August, 1972	SW-137-1
31	Central Ferry, Washington	Nugaines wheat	August, 1972	SW-72/3-1
32	Pullman, Washington	Michigan Amber wheat	August, 1972	SW-72/32-1
33	Royal Slope, Washington	Michigan Amber wheat	August, 1972	SW-72/33-1

[1] S = single spore; W = wheat; SP = single pustule; T = triticale; E = <u>Elymus</u> sp.

to be kept longer than six weeks was stored in liquid nitrogen. Uredospores retrieved from the liquid nitrogen storage were heat shocked at 40 C for two min. in a water bath prior to use, to improve their germinability (Loegering et al., 1961; Loegering and Harman, 1962).

The U. S. differential varieties selected by Line et al. (1970) for differentiating races of P. striiformis in the United States and the Oregon differential varieties selected by Beaver (1969) were used in race identification (see Table 2). Only ten of the varieties listed by Beaver are required to identify the known races of stripe rust in the Pacific Northwest.

The plants were grown in vermiculite in 4-inch plastic pots in a growth chamber programmed for a 2 C/18 C (night/day) temperature profile with 1,000 ft candles of light during the 12 hr., 18 C day period. The plants were sub-irrigated with Hoagland's nutrient solution.

The seedlings were inoculated by making a suspension of uredospores in freon-113 (trichlorotrifluoroethane) (Miller, 1965) which was sprayed at the plants at a distance of 8-10 inches with a DeVilbiss #15 atomizer. Freon gives excellent dispersion of spores and evaporates quickly giving a uniform distribution of dry spores on the foliage. All race identification tests were made using 8-10 mg of uredospores suspended in 20 ml of freon 113 and atomized onto both sets of differentials at the same time when the plants were at one-leaf stage of

Table 2. Differential wheat varieties used to identify Pacific Northwest races of stripe rust.

Number	Differential Variety	CI or PI No.	Number	Differential Variety	CI or PI No.
		Oregon Differentials			
1	Cappelle Desprez	262223	6	Ibis	--
2	Chinese 166	11765	7	Leda	--
3	Druchamp	11723	8	Moro	13740
4	Flamingo	260899	9	Omar	13073
5	Golden	10063	10	Yamhill	14563
		Oregon Supplemental Varieties			
1	Dippes Triumph	--	4	Michigan Amber	11371
2	Etiole de Choisy	262231	5	Rubis	--
3	Gaines	13448	6	Suwon 92 x Omar^4	13749
		U. S. Differentials			
1	Lemhi	11415	4	Moro	13740
2	Chinese 166	11765	5	Suwon 92 x Omar^4	13749
3	Heines VII	201195	6	Druchamp	13723
			7	Riebesel 47-51	295999

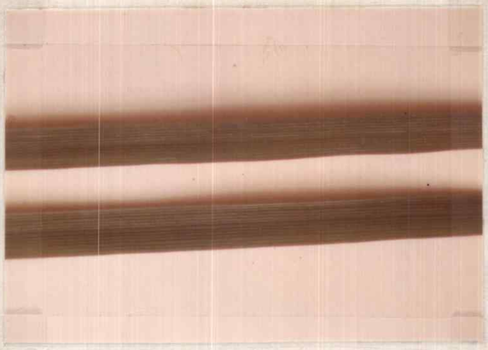
growth. This procedure gave a density of about 400-600 uredospores per cm^2 of leaf surface when applied to 23 pots containing 12-14 plants each. Immediately after inoculation the plants were placed in a dew chamber for 20 to 24 hr. Temperature in the dew chamber was 18 C. After the dew treatment the plants were returned to the growth chamber.

Infection types (IT's) on the differential hosts were determined 18 to 20 days after inoculation. The IT scale employed was that described by Beaver (1969) (Table 3 and Figure 1). When the replicated results on one cultivar varied more than one IT unit, the range was recorded; otherwise the highest IT was recorded.

Table 3. Infection types and symptoms used for characterizing the virulence of Puccinia striiformis isolates.

i	No symptoms observed
oo	No pustules, only minute chlorotic flecks
00	No pustules, only small angular chlorotic or necrotic patches
0	No pustules, only general chlorosis or necrosis
1	Some separated, very small pustules accompanied by chlorosis or necrosis
2	A few pustules, also chlorosis, perhaps necrosis
3	Normal pustule formation, also chlorosis
4	Normal pustule formation without chlorosis

Figure 1. Range of infection types used to characterize the virulence of *Puccinia striiformis* isolates.



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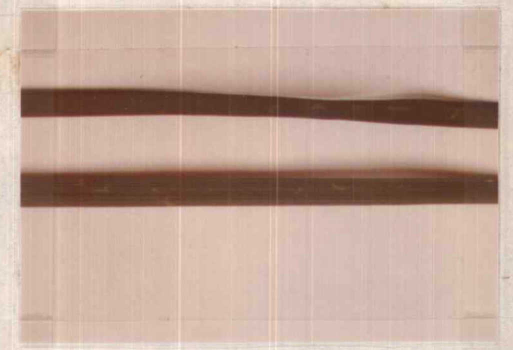

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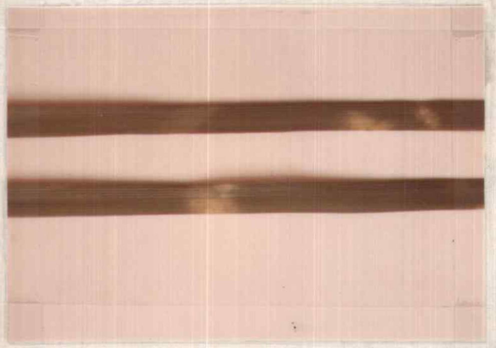

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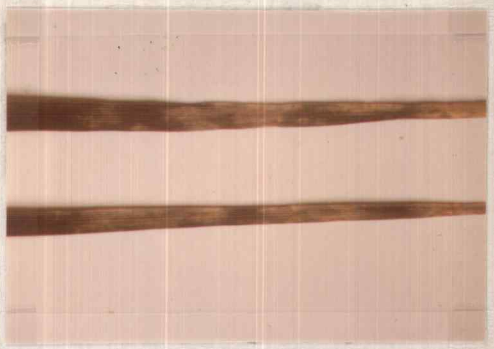

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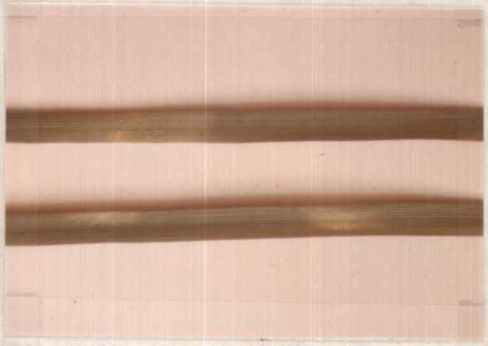

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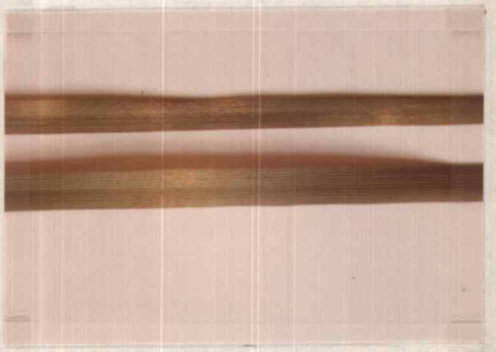

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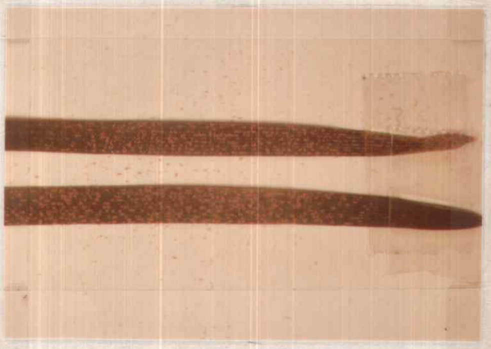

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RESULTS

The virulence of 44 isolates of P. striiformis West. (Table 1) was determined using the "Oregon" (Beaver, 1969, 1972) and "U.S." (Line, Sharp and Powelson, 1970) sets of differential varieties (Table 4 and 5). The isolates represent 31 field collections obtained from wheat, and one each from triticale and Elymus condensatus plants during 1971 and 1972 in the Pacific Northwest. Race identification was based on two different susceptible infection classes depending upon whether IT 2 was considered susceptible or resistant.

The races of stripe rust previously described by Beaver (1969, 1972) in the Pacific Northwest and all the races identified in this study could be differentiated by the use of only ten of the 16 differential varieties listed by Beaver (1972) (Table 2). Thus, only ten varieties were used in the decanery system of race naming (Habgood, 1970; Johnson et al., 1972) which has been used to report the results of this study. In this recently proposed system differential varieties were arranged in a fixed numerical order; for example, ten varieties were arranged 1 to 10. These varieties were assigned numerical values based upon the use of binary notation which was converted to decanery values for each variety, e.g., where 1=1, 2=2, 3=4, 4=8, 5=16, etc. The sum of decanery values of differential varieties on which the race was virulent was used to designate the race. This number is unique

Table 4. Infection types of 44 isolates of <u>Puccinia striiformis</u> on the Oregon differential varieties of winter wheat in the seedling stage at a 2C/18C temperature profile.[1]

Variety	ISOLATE																					
	W-96	SW-96-1	SW-98-1	SW-128-1	SW-95-3	SW-102-1	SW-136-1	ST-99-1[2]	SW-131	SW-131-3	SW-131-4	SW-131-5	SW-131-6	SW-104-1	W-97	W-132	SW-132-1	SW-101-1	W-127	SW-105-1	SW-107-1	SW-130-1
Cappelle Desprez	0	0	0	0	3	3	3	2	2	2	2	2	2	00	i	i	i	2	1	oo	00	00
Chinese 166	oo	oo	oo	0	0	1	0	00	00	00	00	00	00	oo	1	1	1	1	0	3	00	00
Dippes Triumph	3	3	3	3	3	3	4	3	3	3	3	3	3	2	2	2	2	3	3	3	00	00
Druchamp	oo	oo	oo	00	3	3	3	3	3	3	3	3	3	00	oo	i	i	00	0	00	3	3
Etiole de Choisy	3	3	3	3	3	3	3	4	4	4	4	4	4	3	0	i	i	3	3	2	0	0
Flamingo	0	0	0	0	3	4	3	4	4	4	4	4	4	3	0	i	i	3	3	2	0	0
Gaines	3	3	3	3	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4	3	3
Golden	3	3	3	3	4	3	3	3	3	3	3	3	3	3	0-3	3	3	2	2	3	0	0
Ibis	0-2	0-2	0-2	0-2	i	0	i	00	00	00	00	00	00	oo	0	oo	oo	00	00	1	00	00
Leda	4	4	4	3	3	3	3	3	3	3	3	3	3	3	00	00	00	1	2	2	oo	oo
Michigan Amber	3	3	3	3	3	3	3	4	4	4	4	4	4	3	4	3	3	3	3	4	0	0
Moro	i	i	i	0	i	00	i	00	i	i	i	i	i	3	i	i	i	i	oo	oo	i	i
Omar	3	3	3	3	4	3	4	4	3	3	3	3	3	3	1	1	1	3	3	3	2	2
Rubis	4	4	4	3	00-2	00-2	00-2	3	3	3	3	3	3	4	4	3	3	3	3	2	2	2
Suwon 92 x Omar[4]	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	i	i	00	1	00	1	1
Yamhill	0	0	0	0	00	00	00	3	3	3	3	3	3	00	00	00	00	00	1	oo	00	00

Table 4. Continued.

Variety	ISOLATE																					
	SW-134-1	SW-108-1	SW-112-1	W-112	SW-123-1	SW-125-2	SE-135-1[3]	SW-137-1	SW-126-1	SW-118-1	SW 72/33-1	SW-110-1	SPW-111-1	SW-116-1	SW-120-1	W-125	SW-125-1	SW-129-1	SW-131-1	SW-131-2	SW 72/3-1	SW 72/32-1
Cappelle Desprez	1	00	i	i	00	oo	oo	0	00	0	00	oo	oo	oo	00	3	3	3	3	3	oo	1
Chinese 166	00	00	00	00	00	0	0	0	2	2	2	00	00	1	i	00	00	00	i	i	2	3
Dippes Triumph	2	3	3	3	3	3	3	3	3	3	3	1	3	3	oo	3	3	3	4	4	1-3	3
Druchamp	3	0	i	i	i	oo	oo	0	1	0	00	00	oo	i	oo	1	1	1	3	3	00	oo
Etiole de Choisy	2	3	3	3	4	3	3	3	3	4	3	2	3	3	oo	3	3	3	4	4	3	3
Flamingo	2	4	4	4	3	3	4	3	3	3	3	3	3	3	3	3	3	3	2	2	3	3
Gaines	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	3	3	3	4	4
Golden	2	4	3	3	3	3	3	3	3	3	4	2	4	3	oo	3	3	3	i	i	3	2
Ibis	oo	oo	00	00	i	0	i	0	oo	0	0	i	00	1	i	i	i	oo	oo	oo	3	2
Leda	1	3	3	3	3	3	3	3	4	3	3	2	1	00	00	3	3	3	3	3	3	3
Michigan Amber	i	4	3	3	3	4	4	4	3	3	3	4	4	3	i	3	3	3	i	i	3	3
Moro	oo	i	i	i	00	00	i	oo	oo	oo	oo	oo	1	oo	00	i	i	0	i	i	oo	1
Omar	i	4	3	3	3	3	3	4	3	3	3	4	i	1	1	3	3	3	4	4	3	3
Rubis	00	4	3	3	3	4	3	3	3	4	3	4	3	3	00	3	3	3	3	3	3	4
Suwon 92 x Omar[4]	00	i	00	00	00	00	00	oo	00	oo	00	00	00	i	i	00	00	00	i	i	00	00
Yamhill	0	0	0	0	1	1	i	1	00	0	1	3	1	00	00	i	i	i	i	i	1	1

[1] Average of two or three different replicated tests. Isolates SW-104-1, SW-116-1 and SW-120-1 evaluated only once.

[2] Triticale isolate.

[3] *Elymus condensatus* isolate.

Table 5. Infection types of 44 isolates of Puccinia striiformis on the "U. S." differential varieties in the seedling stage at a 2C/18C temperature profile.[1]

Variety	ISOLATE																					
	W-96	SW-96-1	SW-98-1	SW-108-1	SW-110-1	SPW-111-1	SW-112-1	W-112	SW-116-1	SW-120-1	SW-123-1	SW-125-2	SW-128-1	SE-135-1[3]	SW-137-1	SW-101-1	W-127	ST-99-1[2]	SW-131-3	SW-131-4	SW-131-5	SW-131-6
1 Lemhi	3	3	3	3	3	3	4	4	4	3	3	4	3	3	3	3	3	3	4	4	4	4
2 Chinese 166	oo	oo	oo	00	00	00	00	00	1	i	00	0	0	0	0	1	0	00	00	00	00	00
3 Heines VII	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	2	2	3	3	3	3	3
4 Moro	i	i	i	i	oo	1	i	i	oo	00	00	00	0	i	oo	i	oo	00	i	i	i	i
5 Suwon 92 x Omar[4]	00	00	00	i	00	00	00	00	i	i	00	00	00	00	oo	00	1	00	00	00	00	00
6 Druchamp	oo	oo	oo	0	00	oo	i	i	i	oo	i	oo	00	oo	0	00	0	3	3	3	3	3
7 Riebesel 47-51	oo	oo	oo	00	oo	00	i	i	oo	i	i	oo	00	oo	oo	i	0	oo	oo	oo	oo	oo

Table 5. Continued.

Variety	ISOLATE																					
	W-131	SW-95-3	SW-102-1	SW-136-1	SPW-134-1	SW-107-1	SW-130-1	SW-131-1	SW-131-2	W-97	SW-125-1	W-125	W-132	SPW-132-1	SW-129-1	SW-104-1	SW-105-1	SW-126-1	SW-118-1	SW 72/3-1	SW 72/33-1	SW 72/32-1
1 Lemhi	4	3	3	3	2	2	2	3	3	3	3	3	3	3	3	3	4	4	3	4	3	3
2 Chinese 166	00	0	1	0	00	00	00	i	i	1	00	00	1	1	00	oo	3	2	2	2	2	3
3 Heines VII	3	2	2	2	2	00	00	1	1	1	1	1	1	1	1	3	1	3	3	3	3	2
4 Moro	i	i	00	i	i	i	i	i	i	i	i	i	i	i	0	3	oo	oo	oo	oo	oo	1
5 Suwon 92 x Omar[4]	00	00	00	0	00	1	1	i	i	00	00	00	i	i	00	00	oo	00	oo	00	00	00
6 Druchamp	3	3	3	3	3	3	3	3	3	oo	1	1	i	i	1	00	00	1	0	00	00	oo
7 Riebesel 47-51	oo	oo	i	i	0	00	00	i	i	oo	00	00	oo	oo	i	i	i	i	oo	oo	oo	oo

[1] Average of two or three different replicated tests. Isolates SW-104-1, SW-116-1, and SW-120-1 evaluated only once.

[2] Triticale isolate.

[3] *Elymus condensatus* isolate.

in that it can only be derived by summation of the values assigned to the varieties on which the race is virulent.

Race Identification on Oregon Differential Varieties

Sixteen races were identified on the "Oregon" set of differential varieties and assigned both a decanery race number and conventional Oregon race designation (Table 6). The race designations changed, depending on whether IT 2 was considered a susceptible or resistant reaction. Ten out of 16 races (group A and B, Table 7) identified on the basis of an IT 2 susceptible reaction remained in the same race groups as they did when only IT's of 3 and 4 were considered susceptible (Table 7). The other six races (group C, Table 7) could be divided into nine races when both reaction class combinations were considered. The virulence of seven races (group A, Table 7) was the same for both reaction classes while three races (group B, Table 7) produced IT's of 2 on Cappelle Desprez, Golden and Leda or Flamingo, which increased their decanery number, but they remained in the same race group. However, the identification of the six races in group C (Table 7) was changed when both reaction classes were considered. An IT 2 on either one or two of the varieties Cappelle Desprez, Leda, Chinese 166, Golden, Ibis and Omar resulted in the isolates in group C (Table 7) to be grouped in a different array of races. For example, some isolates of race OR 106 (3, 4 IT) give an IT 2 on Chinese 166 and

Table 6. Identification and designation of physiologic races of Puccinia striiformis from 44 isolates on the Oregon differential varieties.

Collection No.	Isolates	Oregon Race	Varieties and decanery value: Cappelle Desprez 512	Chinese 166 256	Druchamp 128	Flamingo 64	Golden 32	Ibis 16	Leda 8	Moro 4	Omar 2	Yamhill 1	Decanery Race No.[1]	Decanery Race No.[2]
2	W-96	OR 8-69					32		8		2		42	42
2	SW-96-1	OR 8-69					32		8		2		42	42
4	SW-98-1	OR 8-69					32		8		2		42	42
22	SW-128-1	OR 8-69					32		8		2		42	42
1	SW-95-3	Druchamp	512[3]		128	64	32		8		2		746	746
7	SW-102-1	Druchamp	512		128	64	32		8		2		746	746
29	SW-136-1	Druchamp	512		128	64	32		8		2		746	746
5	ST-99-1	Yamhill	(512)[4]		128	64	32		8		2	1	235	747
25	W-131	Yamhill	(512)		128	64	32		8		2	1	235	747
25	SW-131-3	Yamhill	(512)		128	64	32		8		2	1	235	747
25	SW-131-4	Yamhill	(512)		128	64	32		8		2	1	235	747
25	SW-131-5	Yamhill	(512)		128	64	32		8		2	1	235	747
25	SW-131-6	Yamhill	(512)		128	64	32		8		2	1	235	747
8	SW-104-1	Moro				64	32		8	4	2		110	110
3	W-97	OR 10-71					32						32	32
26	W-132	OR 10-71					32						32	32
26	SW-132-1	OR 10-71					32						32	32
6	SW-101-1	OR 11-71	(512)			64	(32)				2		66	610
21	W-127	OR 20-72				64	(32)		(8)		2		66	106
9	SW-105-1	OR 12-71		256		(64)	32		(8)		2		290	362
10	SW-107-1	OR 13-71			128						(2)		128	130
24	SW-130-1	OR 13-71			128						(2)		128	130
27	SW-134-1	OR 21-72			128	(64)	(32)						128	224

Table 6. Continued.

Collection No.	Isolates	Oregon Race	Varieties and decanery value										Decanery Race No.[1]	Decanery Race No.[2]
			Cappelle Desprez	Chinese 166	Druchamp	Flamingo	Golden	Ibis	Leda	Moro	Omar	Yamhill		
			512	256	128	64	32	16	8	4	2	1		
11	SW-108-1	OR 14-71				64	32		8		2		106	106
14	SW-112-1	OR 14-71				64	32		8		2		106	106
14	W-112	OR 14-71				64	32		8		2		106	106
18	SW-123-1	OR 14-71				64	32		8		2		106	106
19	SW-125-2	OR 14-71				64	32		8		2		106	106
28	SE-135-1	OR 14-71				64	32		8		2		106	106
30	SW-137-1	OR 14-71				64	32		8		2		106	106
20	SW-126-1	OR 19-71		(256)		64	32		8		2		106	362
16	SW-118-1	OR 19-71		(256)		64	32		8		2		106	362
33	SW-72/33-1	OR 19-71		(256)		64	32		8		2		106	362
12	SW-110-1	OR 15-71				64	(32)		(8)		2	1	67	107
13	SPW-111-1	OR 16-71				64	32						96	96
15	SW-116-1	OR 16-71				64	32						96	96

Table 6. Continued.

Collection No.	Isolates	Oregon Race	Varieties and decanery value										Decanery Race No.[1]	Decanery Race No.[2]
			Cappelle Desprez	Chinese 166	Druchamp	Flamingo	Golden	Ibis	Leda	Moro	Omar	Yamhill		
			512	256	128	64	32	16	8	4	2	1		
17	SW-120-1	OR 17-71				64							64	64
19	W-125	OR 18-71	512			64	32		8		2		618	618
19	SW-125-1	OR 18-71	512			64	32		8		2		618	618
23	SW-129-1	OR 18-71	512			64	32		8		2		618	618
25	SW-131-1	OR 22-72	512		128	(64)			8		2		650	714
25	SW-131-2	OR 22-72	512		128	(64)			8		2		650	714
31	SW 72/3-1	OR 23-72		(256)		64	32	16	8		2		122	378
32	SW 72/32-1	OR 24-72		256		64	(32)	(16)	8		2		330	378

[1] IT 3,4=susceptible.

[2] IT 2,3 and 4=susceptible.

[3] Decanery value of varieties.

[4] An IT **2** reaction is indicated by ( ).

Table 7. Physiologic races of <u>Puccinia striiformis</u> identified on the selected Oregon differential varieties.

Varieties and decanery value												
Cappelle Desprez	Chinese 166	Druchamp	Flamingo	Golden	Ibis	Leda	Moro	Omar	Yamhill	Decanery Race No.[1]	Decanery Race No.[2]	Dual Decanery Race No.[3]
512	256	128	64	32	16	8	4	2	1			
				Group A								
				32						32	32	32-32
				32		8		2		42	42	42-42
			64							64	64	64-64
			64	32						96	96	96-96
			64	32		8	4	2		110	110	110-110
512[3]			64	32		8		2		618	618	618-618
512		128	64	32		8		2		746	746	746-746
				Group B								
			64	(32)		(8)		2	1	67	107	67-107
(512)[4]		128	64	32		8		2	1	235	747	235-747
512		128	(64)			8		2		650	714	650-714

Table 7. Continued.

Varieties and decanery value												
Cappelle Desprez 512	Chinese 166 256	Druchamp 128	Flamingo 64	Golden 32	Ibis 16	Leda 8	Moro 4	Omar 2	Yamhill 1	Decanery Race No.[1]	Decanery Race No.[2]	Dual Decanery Race No.[3]
				Group C								
		128						(2)		128	130	128-130
		128	(64)	(32)						128	224	128-224
(512)			64	(32)				2		66	610	66-610
			64	(32)		(8)		2		66	106	66-106
			64	32		8		2		106	106	106-106
	(256)		64	32		8		2		106	362	106-362
	256		(64)	32		(8)		2		290	362	290-362
	256		64	(32)	(16)	8		2		330	378	330-378
	(256)		64	32	16	8		2		122	378	122-378

[1] IT 3, 4=susceptible.

[2] IT 2, 3 and 4=susceptible.

[3] Decanery value of varieties.

[4] An IT 2 reaction is indicated by ( ).

would be designated race OR 362. Thus, on a dual IT system of race classification we would have races OR 106-106 and OR 106-362. When the combination of decanery numbers of both reaction classes were considered, nine races could be differentiated.

Race Identification on "U. S." Differentials

Seven races were identified on the "U. S." set of differential varieties (Table 8). These seven races can be designated on the avirulent/virulent formula of Line *et al.* (1970) where IT's 2, 3 and 4 are listed to the right of the slash or by their decanery value (Habgood, 1970; Johnson, *et al.*, 1972).

The seven "U. S." races can be further divided into 12 races when the interactions of 2, 3, 4 IT's and 3, 4 IT's are considered (Table 9). Only "U. S." races 1, 3 and 13 showed the same virulence for both reaction classes.

Occurrence of Races from 1964-1972

In 1971 and 1972, 19 physiologic races of *P. striiformis* West. were identified in the Pacific Northwest. Four of the 19 races were previously described by Beaver (1969, 1972) (Table 10). The remaining 15 races are new based on their virulence on the Oregon differentials. Other workers in the United States have identified races of stripe rust (Bever, 1934; Purdy and Allan, 1966; Sharp, 1962, 1965; Sharp and

Table 8. Identification and designation of physiologic races of <u>Puccinia</u> <u>striiformis</u> on "U. S." differential varieties.

Collection No.	Isolates	Varieties and decanery value: Riebesel 47-51 64	Druchamp 32	Suwon 92 x Omar[4] 16	Moro 8	Heines VII 4	Chinese 166 2	Lemhi 1	Decanery Race No.[1]	U. S. Race Designation	Decanery Race No.[2]
2	W-96					4		1	5	4,2,6,7,5/1,3	5
2	SW-96-1					4		1	5	4,2,6,7,5/1,3	5
4	SW-98-1					4		1	5	4,2,6,7,5/1,3	5
11	SW-108-1					4		1	5	4,5,2,7,6/1,3	5
12	SW-110-1					4		1	5	4,7,2,5,6/1,3	5
13	SPW-111-1					4		1	5	6,2,5,7,4/1,3	5
14	SW-112-1					4		1	5	4,6,7,2,5/3,1	5
14	W-112					4		1	5	4,6,7,2,5/3,1	5
15	SW-116-1					4		1	5	5,6,4,7,2/1,3	5
17	SW-120-1					4		1	5	2,5,7,6,4/1,3	5
18	SW-123-1					4		1	5	6,7,2,4,5/1,3	5
19	SW-125-2					4		1	5	6,7,4,5,2/3,1	5
22	SW-128-1					4		1	5	5,6,7,2,4/1,3	5
28	SE-135-1					4		1	5	4,6,7,5,2/1,3	5
30	SW-137-1					4		1	5	4,5,7,2,6/1,3	5
6	SW-101-1					(4)[4]		1	5	4,7,5,6,2/3,1	1

Table 8. Continued.

Collection No.	Isolates	Riebesel 47-51 64	Druchamp 32	Suwon 92 x Omar[4] 16	Moro 8	Heines VII 4	Chinese 166 2	Lemhi 1	Decanery Race No.[1]	U. S. Race Designation	Decanery Race No.[2]
		Varieties and decanery value									
21	W-127					(4)[4]		1	5	4,2,6,7,5/3,1	1
5	ST-99-1		32[3]			4		1	37	2,7,4,5/1,3,6	37
25	SW-131-3		32			4		1	37	4,7,5,2/3,6,1	37
25	SW-131-4		32			4		1	37	4,7,5,2/3,6,1	37
25	SW-131-5		32			4		1	37	4,7,5,2/3,6,1	37
25	SW-131-6		32			4		1	37	4,7,5,2/3,6,1	37
25	W-131		32			4		1	37	4,7,5,2/3,6,1	37
1	SW-95-3		32			(4)		1	37	4,7,5,2/3,1,6	33
7	SW-102-1		32			(4)		1	37	7,4,5,2/3,1,6	33
29	SW-136-1		32			(4)		1	37	4,7,2,5/3,1,6	33
27	SPW-134-1		32			(4)		(1)	37	4,2,5,7/1,3,6	32
10	SW-107-1		32					(1)	33	4,2,3,7,5/1,6	32
24	SW-130-1		32					(1)	33	4,2,3,7,5/1,6	32
25	SW-131-1		32					1	33	2,4,5,7,3/1,6	33
25	SW-131-2		32					1	33	2,4,5,7,3/1,6	33
3	W-97							1	1	4,6,7,5,2,3/1	1
19	SW-125-1							1	1	4,2,5,7,3,6/1	1
19	W-125							1	1	4,2,5,7,3,6/1	1

Table 8. Continued.

Collection No.	Isolates	Varieties and decanery value							Decanery Race No.[1]	U. S. Race Designation	Decanery Race No.[2]
		64	32	16	8	4	2	1			
26	W-132							1	1	4,5,6,7,2,3/1	1
26	SPW-132-1							1	1	4,5,6,7,2,3/1	1
23	SW-129-1							1	1	7,2,5,4,3,6/1	1
8	SW-104-1				8	4		1	13	7,2,5,6/1,3,4	13
9	SW-105-1						2	1	3	7,4,5,6,3/1,2	3
20	SW-126-1					4	(2)	1	7	7,4,5,6/2,3,1	5
16	SW-118-1					4	(2)	1	7	4,5,7,6/2,1,3	5
31	SW 72/3-1					4	(2)	1	7	4,7,5,6/2,3,1	5
33	SW 72/33-1					4	(2)	1	7	4,7,5,6/2,1,3	5
32	SW 72/32-1					(4)	2	1	7	7,6,5,4/3,1,2	3

[1] IT 2,3 and 4=susceptible.

[2] IT 3 and 4=susceptible.

[3] Figures refer to the decanery values of differential varieties on which the isolates produce an IT of 3,4.

[4] An IT 2 reaction is indicated by ( ).

Table 9. Physiologic races of <u>Puccinia</u> <u>striiformis</u> identified on the "U. S." differential varieties.

U. S. Race (2, 3, 4)	Riebesel 47-51 64	Druchamp 32	Suwon 92 x Omar[4] 16	Moro 8	Heines VII 4	Chinese 166 2	Lemhi 1	Decanery Race No.[1]	Decanery Race No.[2]	Dual Decanery Race No.[1,2]
	Varieties and decanery value									
7,4,5,6,3/1,2						2	1	3	3	3-3
7,6,5,4/3,1,2					(4)[4]	2	1	7	3	7-3
4,7,5,6/2,3,1					4	(2)	1	7	5	7-5
4,2,6,7,5/1,3					4		1	5	5	5-5
4,2,6,7,5/3,1					(4)		1	5	1	5-1
4,5,6,7,2,3/1							1	1	1	1-1
7,2,5,6/1,3,4				8	4		1	13	13	13-13
4,2,3,7,5/1,6		32[3]					(1)	33	32	33-32
7,4,5,2,3/1,6		32					1	33	33	33-33
4,7,5,2/3,1,6		32			(4)		1	37	33	37-33
4,7,5,2/3,6,1		32			4		1	37	37	37-37
4,2,5,7/1,3,6		32			(4)		(1)	37	32	37-32

[1] IT 2, 3 and 4=susceptible.

[2] IT 3 and 4=susceptible.

[3] Decanery value of variety.

[4] IT 2 reaction is indicated by ( ).

Table 10. Occurrence of physiologic races of *Puccinia striiformis* in the Pacific Northwest from 1964-1972.

Races		Years identified									
Decanery	Oregon	64	65	66	67	68	69	70	71	72	Host
OR 330-330	OR 1-64	+									Baart
OR 330-378	OR 24-72									+	Michigan Amber
OR 34-34	OR 2-64	+									Baart
OR 40-40	OR 3-65		+								*Elymus cinereus*
OR 18-18	OR 4-67				+						*Bromus marginatus*
OR 256-256	OR 5-67				+						Omar
OR 24-88	OR 6-67				+						Gaines
OR 44-44	OR 7-68					+					Gaines
OR 42-42	OR 8-69						+		+	+	Nugaines, Orin, winter wheat
OR 362-490	OR 9-69						+				Suwon x Burt
OR 110-110	Moro					+			+		Moro
OR 746-746	Druchamp							+	+	+	Druchamp, Nugaines, Omar
OR 32-32	OR 10-71								+	+	unknown wheat, Omar
OR 96-96	OR 16-71								+		Michigan Amber, PI 167822/101
OR 64-64	OR 17-71								+		Wanser
OR 618-618	OR 18-71								+	+	Gaines, unknown wheat
OR 235-747	Yamhill							+	+	+	Yamhill, Gaines, triticale
OR 67-107	OR 15-71								+		Nugaines
OR 650-714	OR 22-72									+	Gaines
OR 66-610	OR 11-71								+		Nugaines
OR 66-106	OR 20-72									+	Gaines
OR 106-106	OR 14-71								+	+	Luke, Gaines, Anzer, Yamhill, *Elymus condensatus*

Table 10. Continued.

Races		Years identified									
Decanery	Oregon	64	65	66	67	68	69	70	71	72	Host
OR 106-362	OR 19-71								+	+	Wanser, Omar, Michigan Amber
OR 290-362	OR 12-71								+		unknown wheat
OR 122-378	OR 23-72									+	Nugaines
OR 128-130	OR 13-71								+	+	Nugaines, unknown wheat
OR 128-224	OR 21-72									+	Gaines

Volin, 1970; Stubbs, 1972; Tollendaar and Houston, 1967), but they used different sets of differential varieties and there is no direct way to compare results.

When a dual system of decanery race designation is used, where both reaction classes are given, no race was identified in more than three years during the period 1964-1972. Race OR 42-42 which was first observed in 1969 (Beaver, 1969) was found in both 1971 and 1972. Race OR 110-110 which is pathogenic to Moro wheat and first detected in the Pacific Northwest in 1968 (Beaver and Powelson, 1969) was identified again in 1971. The races OR 746-746 and OR 235-747 which were first collected from Druchamp and Yamhill, respectively, in 1970 (Beaver, 1972) were again present in the population in 1971 and 1972 and were recovered from varieties other than Druchamp and Yamhill.

Certain races when evaluated on the dual system of race identification showed a shift in virulence. For example, race OR 330-330 (Beaver, 1969) which was first detected in 1964 is similar to race OR 330-378 which was identified in 1972 and differs from OR 330-330 by producing at IT of 2 on Golden and Ibis which were highly resistant in 1964. Similar results were also obtained for races OR 66-610, OR 128-130 and OR 106-106.

Races OR 235-747 and OR 106-106 which were recovered from wheat were also isolated from triticale and *Elymus condensatus*, respectively. However, none of the wheat isolates gave the races OR 40-40 and OR 18-18 which were identified by Beaver (1969) from *Elymus cinereus* and *Bromus marginatus*, respectively.

Race Distribution and Frequency of Occurrence

The distribution of OR races was evaluated by grouping collections into five different wheat growing areas of the Pacific Northwest based on geographic and ecological differences (Figure 2 and Table 11). The five areas were designated: 1) Willamette Valley; 2) Lower Columbia Basin; 3) Pendleton-Walla Walla; 4) Upper Columbia Basin; and 5) Pullman-Moscow.

Race OR 106-106 was the most widely distributed race in the Pacific Northwest and was found in all areas with the exception of the Upper Columbia Basin. However, the closely related race OR 106-362 was found in the Upper Columbia Basin and the Pendleton-Walla Walla area. Race OR 106-362 was obtained from different varieties than race OR 106-106. The widespread distribution of race OR 106-106 may be related to its ability to attack a wide range of commercially grown Pacific Northwest wheat varieties. This race was recovered from four varieties and also Giant Wild Rye (*Elymus condensatus*). Race OR 106-106 was also the most frequently isolated. However, this amounted to only six of 33 collections made in 1971 and 1972.

Figure 2. Wheat growing regions of the Pacific Northwest showing five areas from which stripe rust collections were made: (1) Willamette Valley; (2) Lower Columbia Basin; (3) Pendleton-Walla Walla; (4) Upper Columbia Basin; (5) Pullman-Moscow.

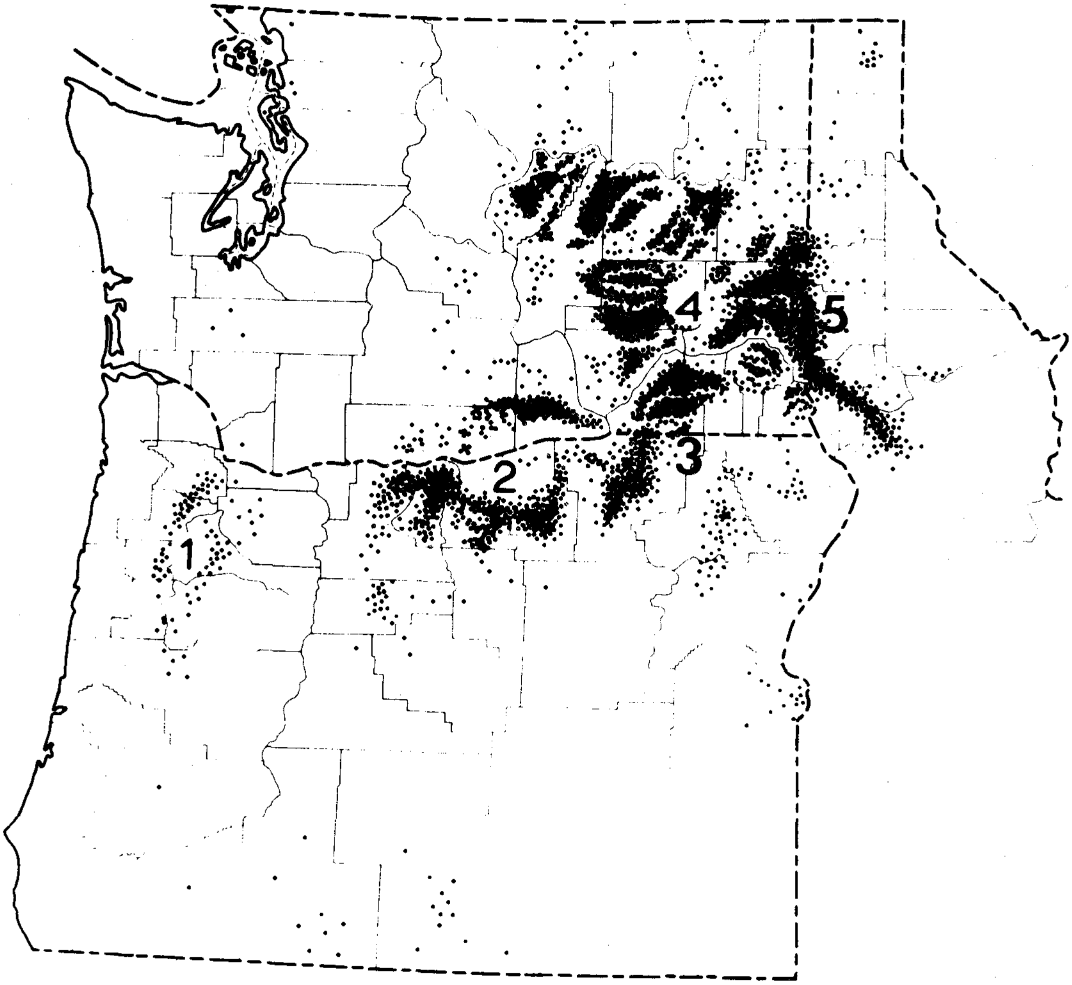
1
2
3
4
5

Table 11. Distribution and frequency of occurrence of physiologic races of Puccinia striiformis collected in the Pacific Northwest during 1971 and 1972.

Area	RACES																				
	OR 32-32	OR 42-42	OR 64-64	OR 96-96	OR 110-110	OR 746-746	OR 618-618	OR 235-747	OR 67-107	OR 650-714	OR 66-610	OR 66-106	OR 106-106	OR 106-362	OR 290-362	OR 330-378	OR 122-378	OR 128-130	OR 128-224	Total Collections	Total Isolates	Total races
1. Willamette Valley		0/1				2/0	1/1	1/0[2]			1/0		2/0					0/1		6/3	9/3	7/3
2. Lower Columbia Basin	0/1[1]	1/0				0/1						0/1	0/1		1/0				0/1	2/5	3/6	2/5
3. Pendleton-Walla Walla					1/0			0/1		0/1			0/1[3]	0/1			0/1			1/4	1/10	1/5
4. Upper Columbia Basin				1/0					1/0					1/1				1/0		4/1	4/1	4/1
5. Pullman-Moscow	1/0	1/0	1/0	1/0									2/0			0/1				6/1	6/1	6/1
TOTAL	1/1	2/1	1/0	2/0	1/0	2/1	1/1	1/1	1/0	0/1	1/0	0/1	4/2	1/2	1/0	0/1	0/1	1/1	0/1	19/14	23/21	20/15

[1]Number of times collected: 1971/1972.

[2]Triticale isolate.

[3]*Elymus* sp. isolate.

Of the seven races which occurred in the Willamette Valley, only races OR 618-618 and OR 66-610, which were isolated from Gaines and Nugaines, respectively, were not found in other areas of the Pacific Northwest. Race OR 235-747 (Yamhill race) which was first detected at Aurora, Oregon, in 1970 on Yamhill (Beaver, 1972) is not unique to the Willamette Valley, where this variety is widely grown. It has also been found on Gaines wheat in the Pendleton-Walla Walla area. All of the areas had one or more races in common with other areas of the Pacific Northwest. However, 11 of the 19 races were specific for one of the five designated wheat growing areas.

A seasonal shift in race population is suggested by the time of collection of race OR 106-106. This was the most frequently isolated race, but it was not found earlier than July. This race may be favored by warmer temperatures which occur later in the season which modifies the virulence of the pathogen or susceptibility of the host, i. e., high temperature conditions a mature plant resistance in Gaines and Nugaines wheat.

The two major wheat varieties (Gaines and Nugaines) grown in the Pacific Northwest produced 11 of the 19 races identified in 1971 and 1972 (Table 12). Moro was the only variety which gave a unique race (OR 110-110). All the other differentials or commercially grown wheats could support two or more races. Another race, OR 330-378

Table 12. Occurrence of races of stripe rust on Gaines and Nugaines in the Pacific Northwest.

Varieties	Area	Time of year	Race
Gaines	Willamette Valley	July, 1971	106-106
Gaines	Willamette Valley	July, 1971	618-618
Gaines	Lower Columbia Basin	April, 1972	66-106
Gaines	Lower Columbia Basin	May, 1972	128-224
Gaines	Pendleton-Walla Walla	May, 1972	714-714
Nugaines	Lower Columbia Basin	May, 1971	96-96
Nugaines	Willamette Valley	June, 1971	66-610
Nugaines	Willamette Valley	June, 1971	746-746
Nugaines	Upper Columbia Basin	July, 1971	128-130
Nugaines	Upper Columbia Basin	July, 1971	67-107
Nugaines	Pullman-Moscow	1972	122-378

which was found only in the Pullman-Moscow area, was the most widely virulent race identified. It produced a virulent response on 14 of 16 Oregon differentials.

More than one race was obtained when single spore isolations were made from a field collection (Table 6). The seven isolates from field Collection No. 25 were designated as race OR 235-747 or OR 650-714. The isolates from Collection 19 gave races OR 106-106 or OR 618-618.

DISCUSSION

Stripe rust identification in the Pacific Northwest has been attempted at various times by several workers (Hungerford and Owens, 1923; Bever, 1934; Purdy and Allan, 1966; Beaver and Powelson, 1969; Line, 1969; Volin and Sharp, 1969; Beaver, 1969, 1972). Each used different sets of differential varieties, and there has been no attempt at systematic evaluation of races. Beaver (1969) developed the Oregon set of 16 differential varieties in 1967 and identified races from collections made between 1964 and 1970. The twelve races he identified were mostly from unique collections and did not represent a random sample of the natural field population.

Since Beaver (1969) developed the "Oregon" set of differential varieties, 27 Pacific Northwest races of stripe rust have been identified on this set of differentials. Twelve races were identified by Beaver (1969, 1972) and 15 new races are reported in this thesis (Table 10).

In 1970, Line *et al.*, published a list of seven wheat varieties to be used as a standard set of stripe rust differentials in an attempt to standardize the race identification in the United States. This "U. S." set of differentials was used by Beaver (1972) to compare races identified on the Oregon differentials. He found that the U. S. differentials did not separate the Yamhill race which had occurred on this newly released variety. Again, in this study it was found that three distinct Pacific Northwest races, OR 42-42, OR 96-96 and OR 106-106 could not be separated on the U. S. differentials as well as other OR races. The Oregon set of differential varieties more adequately reflected the distribution and variation in the rust populations of the Pacific Northwest. The "U. S." set of differential varieties is capable of identifying races virulent on widely used sources of stripe rust resistance such as Moro, Chinese 166, Druchamp, and Suwon 92 x Omar[4], and to this end it is satisfactory (Purdy and Allan, 1966; Lewellen, Sharp and Hehn, 1967; Beaver and Powelson, 1969; Volin and Sharp, 1969).

Race designation by decanery values, as proposed by Habgood (1970) and Johnson, et al. (1972), has the advantage of presenting in a single number the susceptibility of differential varieties and it standardizes the naming of races. The system has flexibility for accommodating new differentials and classification of infection types.

In dividing the resistant and susceptible IT's, most workers consider IT's 3 and 4 to be susceptible and everything else resistant (Fuchs, 1960; Zadoks, 1961; Sharp, 1965; Beaver, 1969; Stubbs, 1972). However, others (Line, 1969; Line, Sharp and Powelson, 1970; Beaver, 1972) have included IT 2 in the susceptible reaction class.

Race identification may be changed depending on whether IT 2 is considered a resistant or susceptible reaction. Other races may be identified by combining decanery values of both susceptibility classes. This dual system of race naming clearly shows differences in virulence based on differential host responses to IT 2 reactions.

The dual system of decanery race designation implies than an IT 2 response is a susceptible reaction and reflects important changes in pathogen virulence and host susceptibility. This may be true for stripe rust because IT 2 reactions are systemic within a single leaf and tend to approach a type 3 reaction over time. Also, considerable amounts of sporulation can occur when the whole leaf is considered. Stripe rust can cause significant yield reductions of certain varieties which give IT 2 reaction. The yield of Gaines wheat, which has mature plant resistance (IT 2) was increased 40 bushels per acre with a single application of the fungicide, dichlorotetrafluroacetone (Powelson, 1965) which gives effective control of stripe rust.

The extent of physiologic specialization of *P. striiformis* in the western United States appears to be extensive (Sharp, 1962; 1965; Purdy and Allan, 1966; Tollenaar and Houston, 1967; Beaver and Powelson, 1969; Volin and Sharp, 1969; Sharp and Volin, 1970; Beaver, 1969, 1972). These workers have reported a great diversity of races in time and space in this huge area. This is not unusual in that the area is larger than The Netherlands and West Germany, where numerous races have been identified, and where there is less climatic diversity. More than half of the collections made during this study were different races. No race was identified more than three times, and no one race has predominated in any area since 1964. Part of the explanation may lie in the frequent change of varieties grown and the genetic diversity of the many recently released varieties. Also, the two major wheat varieties grown in the Pacific Northwest, Gaines and Nugaines, support a large number of different races. Moro was the only variety which was attacked by a single race. This race (OR 110-110) was not identified from any collections made from other varieties or where other races were isolated from Moro. The distribution pattern of races indicates that the stripe rust races in the Pacific Northwest are not area specific, based on geography, climate or host grown. For example, race OR 235-747 which was found for the first time on Yamhill in the Willamette Valley was also recovered from Gaines in the Pendleton-Walla Walla area. Also, OR 746-746 and OR 42-42 which were first found in the Willamette Valley (Beaver, 1972) were detected from collections in the Lower Columbia Basin and the Pullman-Moscow areas. Lack of specificity by host and/or area indicates that this rust has a very dynamic system for genetic variability and adaptation.

In view of the extreme genetic diversity in the stripe rust population, there will always be a potential danger from this rust in the

Pacific Northwest. One effective way to reduce this danger is to develop and maintain genetic diversity in the wheat varieties grown in this area.

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