A Comparison of CERTAIN COMBINATIONS OF OAT VARIETIES AS CROWN RUST DIFFERENTIALS[1]

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INTRODUCTION

The most serious disease of oats in the eastern half of the United States is caused by the fungus *Puccinia coronata* Cda. var. *avenae* Fraser & Led., commonly called crown rust.[3] The chief means of controlling this disease is breeding and growing resistant varieties. Resistance does not necessarily protect a variety from all damage by crown rust but protects it from attack by some races of the rust. New races of crown rust, in some cases more virulent than the old, arise from time to time, apparently as a result of mutation and sexual reproduction. When such races become prevalent, oat varieties that are in common use because of resistance to old races may prove susceptible to the new races and need to be replaced. Different races of the fungus are identified by the reactions they produce on specified varieties of oats. Oat breeders and cereal pathologists are vitally concerned with the occurrence, prevalence, and behavior of races of crown rust and in the selection of oat varieties used to differentiate them.

At present, races of crown rust are commonly identified on a set of 13 oat varieties that were selected by Murphy (*7, 8*)[4] as standard differentials in 1935–36. At that time most of these 13 varieties were being used in breeding new resistant

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[2] The authors wish to acknowledge, with appreciation, that in selecting oat varieties to be tested as a new set of standard differentials for identifying races of crown rust they received invaluable cooperation and assistance from B. Peturson, plant pathologist, Laboratory of Plant Pathology, University of Manitoba; H. A. Rodenhiser, agricultural administrator, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture; H. R. Rosen, formerly plant pathologist, Arkansas Agricultural Experiment Station; and M. B. Moore, plant pathologist, Minnesota Agricultural Experiment Station.

[3] Throughout the remainder of this bulletin, *Puccinia coronata* Cda. var. *avenae* Fraser & Led. is referred to as crown rust.

[4] Italic numbers in parentheses refer to Literature Cited, p. 22.

varieties. Since then, new or formerly unimportant races of the pathogen have become so prevalent in the United States that most of the old standard differential varieties are now susceptible to prevalent races. This bulletin deals with investigations made at Ames, Iowa, in which three different sets of oat varieties were tested as crown rust differentials. The varieties tested included, along with the standard differential varieties, certain newer varieties that resist newly prevalent races of the rust.

REVIEW OF LITERATURE

Hoerner (*3*), in 1919, was the first to demonstrate physiologic specialization of crown rust among oat varieties. He distinguished 4 races of the rust on the basis of differential reactions of 2 varieties of oats, Iowa 73 (Ruakura Rustproof) and Iowa 96 (Green Russian). (A summary of varieties used as differentials by different investigators appears later, in table 3.) His form 1 heavily infected both these varieties. Form 2 was only weakly parasitic on both. Form 3 slightly infected Iowa 73 and severely infected Iowa 96. Form 4 severely infected Iowa 73 and slightly infected Iowa 96. Hoerner's data indicated that more races might have been distinguished by using more varieties as differential hosts.

In 1926 Popp (*12*) reported the use of 3 oat varieties, Sterilis Selection, White Russian, and Green Russian, as differential hosts to distinguish 4 races of crown rust among 22 isolates studied.

Parson (*9*) differentiated 5 races of crown rust in 15 collections by the reaction of 27 selections, varieties, and species of oats. Only 4 of these 27—*Avena sterilis*, Red Rustproof, Ruakura, and Green Mountain—proved to be of any practical use as differential hosts.

In 1930 Murphy (*6*) conducted a similar investigation on a larger scale, using 33 varieties and species of oats and 45 collections of crown rust, 32 from *Avena* and 13 from *Rhamnus*. He found 8 varieties useful as differential hosts and distinguished 9 physiologic races. His results are presented in the following key:

Belar (C. I. 2760)[5] resistant:
- Red Rustproof (C. I. 1079) resistant:
  - College Algerians (C. I. 2052) resistant ..... form 3
  - College Algerians (C. I. 2052) susceptible ..... form 8
- Red Rustproof (C. I. 1079) susceptible:
  - Cowra (C. I. 2761) resistant ..... form 9
  - Cowra (C. I. 2761) susceptible ..... form 7

Belar (C. I. 2760) susceptible:
- Iowa No. 69 (C. I. 2463) resistant:
  - *Avena strigosa* (C. I. 1782) resistant:
    - Anthony (C. I. 2143) resistant ..... form 4
    - Anthony (C. I. 2143) susceptible ..... form 2
  - *Avena strigosa* (C. I. 1782) susceptible ..... form 1
- Iowa No. 69 (C. I. 2463) susceptible:
  - Hawkeye (C. I. 2464) resistant ..... form 6
  - Hawkeye (C. I. 2464) susceptible ..... form 5

Murphy (*7*) continued his investigations by testing approximately 300 varieties of oats for reaction to each of 10 cultures of crown rust. He selected 33 varieties as possible differentials on the basis of these tests, inoculated them with 245 cultures, and eventually selected 11 of them as standard differentials for crown rust races. This set included

[5] "C. I." refers to accession number of the Cereal Crops Section, Field Crops Research Branch.

the varieties used by other investigators as differentials. Murphy observed 15 races previously discovered and numbered them 1 to 15. In addition he identified 18 races that he could not relate to any of those previously described and numbered them 16 to 33.

In 1935 Stakman, Levine, and coworkers (*16*) reported the discovery by Murphy of 4 more races, which were numbered 34 to 37. During the same year Peturson (*11*) reported that by studying the reactions of the differentials established by Murphy to 544 Canadian collections of crown rust he had differentiated 11 races of which 9 (1, 2, 3, 4, 5, 6, 9, 10, and 24) had been described previously. The two new races were designated as 38 and 39.

A new race identified in Australia by W. L. Waterhouse was designated in 1935 [6] as number 40. At about the same time Murphy and Levine (*8*) reported the discovery of a new race, number 41, to which the variety Victoria, resistant to all races previously differentiated, was susceptible. They suggested the addition of Victoria and Bond to the standard set of differential varieties.

Brown (*1*), working in England, identified 4 races with the 11 standard differential varieties. One of these, race 6, had been observed previously in North America and Australia. The remaining 3 had not been described before and were designated as races 42, 43, and 44. Race 43 was found in material obtained from Portugal; races 6, 42, and 44, in collections made in Great Britain. In 1938 Moore, Downie, and Murphy (*5*) reported the discovery of a new race of crown rust that was able to attack Bond, which was regarded as a highly resistant variety at that time. This race was designated as number 45. Race 46 was first described by Murphy.[6] The discovery of race 47 was credited by Murphy [6] to Waterhouse.

Two German investigators, Frenzel and Straib, made finer distinctions in determining races of crown rust than had been made by other investigators. Frenzel (*2*) isolated 55 cultures from 27 collections made in Germany in 1928 and 1929 and tested them on these 9 varieties: 1, Ruakura (C. I. 2025); 2, Uruguay; 3, Red Rustproof (Appler) (C. I. 1815); 4, Bri; 5, Brünings Winter; 6, Green Mountain (C. I. 1892); 7, Odenwälder Strauss; 8, *Avena sterilis* var. *nigra* (C. I. 840–9); and 9, Mortgage. He distinguished 33 separate races in the 55 cultures from the 27 collections. In 1935 and 1936 Straib (*17*) tested 147 collections from different locations in Germany on 15 varieties. Some of these varieties had been used previously by Frenzel, and others corresponded to differential varieties used in the United States. Straib identified 142 races in cultures from the 147 collections. His results were similar to those of Frenzel in that he distinguished a new and distinct race in nearly every collection.

Kingsolver [7] and Kingsolver and Murphy (*4*) compared the reactions of the 13 differential varieties used by Murphy and his coworkers to certain isolates of crown rust with the reactions of the differentials used by Straib to the same isolates.

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[6] MURPHY, H. C. CONTROL OF OAT DISEASES, INCLUDING THE TESTING OF VARIETIES FOR REACTION TO DIFFERENT DISEASES AS A BASIS FOR BREEDING RESISTANT VARIETIES. 1935–51. [Unpublished annual reports. On file Cereal Crops Section, Field Crops Research Branch, Agricultural Research Service, Plant Industry Station, Beltsville, Md.]

[7] KINGSOLVER, C. H. DETERMINATION OF PARASITIC RACES IN PUCCINIA CORONATA AVENAE. 1939. [Unpublished master's thesis. Copy on file Iowa State College Library, Ames.]

In addition to the varieties Green Russian, Victoria, Green Mountain, Red Rustproof (Appler), Sterisel, Glabrota, and Bond, all used by Murphy, Straib used Gigantea, Schwarzhafer, Uruguay 64s, Odenwälder Strauss, Landhafer aus Uruguay [Landhafer], Sandhafer, Flughafer, and Mortgage. The comparative tests were made with 81 single-pustule isolates taken from crown rust collections made in 17 different States.

Among these 81 isolates the 13 varieties used by Murphy differentiated 19 races and the 15 varieties used by Straib differentiated 46. The combination of Murphy's and Straib's varieties differentiated 55 races, and addition of the variety Ukraine (Mutica Ukraine) to this combination resulted in differentiation of a total of 60 races. The largest groups of isolates identified on Murphy's differentials as of a single race were 24 identified as of race 1 and 28 identified as of race 6. These groups were divided by Straib's differentials into 18 races and 16 races, respectively. On the other hand, 12 isolates that induced the same reaction on the varieties used by Straib were divided into 2 races by the reactions of the standard set of 13 differential varieties.

With regard to ratio of number of races identified to number of differential varieties used, the 8 varieties used only by Straib were the most efficient set and the 7 varieties used in common by Murphy and Straib were less efficient than either of the complete sets.

The 19 races identified by Kingsolver [8] and Kingsolver and Murphy (*4*) on the differential varieties used by Murphy included 6 that had not been described previously. These were numbered 48 to 53.

Descriptions of race 54 and races 57 to 100 have not been published, but have been recorded by Murphy.[9] Race 54 was first identified by Peturson in Canada; races 55 and 56 were discovered in South America by Vallega (*18*); the large group of races numbered 57 to 95 were described by Murphy;[9] and races 96 to 100 were discovered in Wales in 1950 by D. J. Griffiths.[10] A race numbered 101 later in the same year (*14*) was first reported by Rosen and Murphy (*13*) in 1951. This race, which attacks both Bond and Victoria, appeared in 51 of the 58 collections of crown rust made in Arkansas in 1950 (*14*).

Races 102 and 104 have been reported by Waterhouse (*19*). (For the status of race 103, see table 1, footnote 3.) Races 105 to 107 are described in this bulletin. Races 108 and 109 have been described, in correspondence with the authors, by Verma and Finkner, respectively. Race 110 was discovered in South America by Silva (*15*).

Average reactions of the standard differential varieties to each of the races identified up to the time of this writing are given in tables 1 and 2. Although races 105 to 107 and 111 to 113 are first discussed in this bulletin, reactions to them as determined by the authors are included in these tables for the sake of completeness.

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[8] See footnote 7.
[9] See footnote 6.
[10] Letter from Griffiths to the junior author dated December 11, 1950.

TABLE 1.—*Average reactions* [1] *of the old differential oat (Avena) varieties, in the seedling stage, to races 1 to 113 of crown rust* [2]

Race	1	2	3	4	5	6	7	8	9	10	11	12	13
	Ruakura	Green Russian	Hawkeye	Anthony	Sunrise	Victoria	Green Mountain	White Tartar	Appler	Sterisel	Belar	Bond	Glabrota
1	4	4	4	4	4	1	4	4	4	4	3	0	0
2	1	0	4	0	0	0	0	0	0	1	0	0	0
3	0	4	4	4	0	1	4	4	0	0	0	0	0
4	3	1	4	0	4	1	x	1	4	4	4	0	0
5	0	1	4	0	4	1	0	0	4	3	4	0	0
6	0	4	4	4	4	1	4	4	4	4	4	0	0
7	4	4	0	0	4	1	0	0	4	4	4	0	0
8	1	3	4	4	0	0	4	4	1	3	2	0	0
9	1	2	3	3	2	0	3	3	1	1	2	0	0
10	4	4	4	4	1	1	1	1	4	4	4	0	0
11	4	4	0	0	2	0	0	4	4	4	4	0	4
12	4	4	0	4	3	1	4	0	4	3	3	0	0
13	4	4	4	4	2	0	4	4	4	0	0	0	3
14	1	4	4	4	1	0	4	4	4	0	0	0	0
15	0	4	4	4	4	0	4	4	4	4	1	0	0
16	1	4	0	0	0	1	1	4	0	0	0	0	4
17	0	4	4	0	4	1	1	4	0	0	0	0	4
18	0	4	0	0	0	0	0	4	0	0	0	1	0
19	0	4	4	1	1	0	1	4	1	0	1	0	0
20	4	4	4	0	4	0	0	0	4	4	4	0	0
21	0	0	4	4	0	0	4	4	4	4	4	0	0
22	0	4	4	0	4	0	0	0	4	4	4	0	0
23	4	4	4	4	0	1	4	4	0	4	2	0	0
24	0	4	4	4	0	0	4	4	0	0	0	0	4
25	4	4	4	0	4	0	4	0	4	4	4	0	0
26	4	4	4	0	4	0	0	4	4	4	4	0	0
27	4	4	4	0	4	0	4	0	4	0	4	0	0
28	4	0	4	1	0	0	4	4	0	3	3	0	0
29	0	2	0	0	0	0	0	0	2	2	0	0	0
30	4	4	4	3	4	1	4	4	4	3	4	0	3
31	3	3	3	x	3	1	3	x	4	4	4	0	0
32	4	x	4	x	x	1	x	x	3	2	x	0	0
33	4	0	3	3	4	0	3	3	4	3	x	4	0
34	4	0	0	0	4	0	0	0	4	4	4	4	0
35	3	0	3	3	2	0	4	4	2	0	1	0	3
36	3	3	4	3	0	0	4	3	0	0	x	0	4
37	4	3	2	2	3	0	2	2	4	0	4	0	0
38	0	0	4	0	0	0	0	0	0	0	0	0	4
39	0	0	4	0	0	0	0	0	0	0	4	0	0
40	4	4	0	0	4	1	4	0	4	4	4	0	0
41	1	2	4	4	4	3	4	4	3	3	4	0	0
42	2	4	3	4	1	0	4	4	1	0	3	0	4
43	4	4	4	4	4	2	4	4	4	3	1	0	0
44	1	1	4	1	0	0	1	4	1	0	2	0	4
45	4	4	3	3	4	2	3	3	4	4	4	0	0
46	3	0	0	0	4	0	0	0	3	3	3	0	0
47	1	4	0	1	4	2	0	1	4	4	4	0	0
48	2	3	2	2	3	2	3	2	4	4	4	0	0
49	1	4	1	2	3	0	4	4	4	4	3	0	0

See footnotes on p. 7.

TABLE 1.—*Average reactions* [1] *of the old differential oat (Avena) varieties, in the seedling stage, to races 1 to 113 of crown rust* [2]—Continued

Race	1	2	3	4	5	6	7	8	9	10	11	12	13
	Ruakura	Green Russian	Hawkeye	Anthony	Sunrise	Victoria	Green Mountain	White Tartar	Appler	Sterisel	Belar	Bond	Glabrota
50	2	2	1	2	4	3	2	4	4	4	4	0	0
51	0	4	4	4	4	0	4	4	0	2	2	0	0
52	2	4	0	0	3	3	3	3	4	4	4	0	0
53	3	2	4	0	4	3	1	3	4	4	4	0	0
54	0	0	0	0	4	0	0	0	4	4	3	0	4
55	1	3	4	4	4	4	4	4	3	3	3	4	0
56	3	4	4	4	3	4	4	3	4	3	3	0	0
57	1	3	4	3	4	2	4	3	4	4	4	4	0
58	1	4	0	4	0	0	0	0	4	3	4	0	0
59	0	4	4	4	0	0	4	3	4	4	3	0	0
60	4	4	4	4	0	0	4	3	4	4	3	0	0
61	2	0	0	0	0	1	0	0	4	4	4	0	0
62	0	0	0	0	4	0	0	0	4	0	0	0	0
63	0	4	3	0	0	0	0	3	3	3	3	0	0
64	0	4	3	0	0	0	0	3	3	0	0	0	0
65	0	0	0	0	0	0	3	3	3	0	0	0	0
66	0	4	4	4	3	0	3	3	4	2	4	0	0
67	0	4	4	4	3	1	4	4	0	0	3	0	3
68	4	4	0	0	4	0	0	0	4	4	4	4	0
69	1	4	0	0	4	0	0	0	4	4	4	4	0
70	0	3	4	4	0	1	4	4	1	3	1	0	3
71	0	4	4	4	3	1	4	4	3	2	0	0	0
72	0	0	0	0	3	0	1	4	0	0	0	0	0
73	2	1	0	0	4	0	0	4	4	4	4	0	0
74	3	4	3	4	3	0	4	4	0	0	1	0	0
75	2	3	4	0	4	0	3	3	4	0	0	0	0
76	0	0	3	4	0	0	4	3	0	4	4	0	0
77	3	0	4	4	4	1	4	4	4	4	4	0	0
78	3	3	0	0	4	2	3	3	4	3	3	0	0
79	3	3	3	3	4	0	4	4	3	0	4	0	0
80	1	0	0	0	0	0	0	3	0	0	0	0	0
81	2	3	2	0	4	0	1	4	3	4	4	0	0
82	2	4	0	3	3	1	3	3	4	3	4	0	0
83	0	4	3	0	3	1	4	3	4	4	4	0	0
84	0	3	3	0	4	1	0	3	3	4	4	0	0
85	3	4	0	0	4	0	3	3	4	4	0	0	0
86	0	1	3	4	3	0	4	0	4	3	3	0	0
87	0	4	0	0	4	0	4	1	4	0	0	4	0
88	3	3	0	0	4	1	4	3	4	4	4	4	0
89	3	3	3	3	3	0	4	4	3	4	3	4	3
90	1	3	2	2	3	1	3	3	4	4	4	4	0
91	3	4	1	3	1	3	1	4	4	4	4	4	0
92	1	1	0	1	4	1	4	3	4	4	4	4	0
93	1	2	1	4	4	1	1	4	4	4	4	4	0
94	0	0	0	3	4	0	4	4	4	4	1	4	0
95	3	3	0	3	3	0	3	3	4	4	4	4	0
96	3	4	0	0	4	1	0	4	0	0	4	0	3

See footnotes on p. 7.

TABLE 1.—*Average reactions* [1] *of the old differential oat (Avena) varieties, in the seedling stage, to races 1 to 113 of crown rust* [2]—Continued

Race	1	2	3	4	5	6	7	8	9	10	11	12	13
	Ruakura	Green Russian	Hawkeye	Anthony	Sunrise	Victoria	Green Mountain	White Tartar	Appler	Sterisel	Belar	Bond	Glabrota
97	4	4	0	0	4	0	4	4	4	0	4	0	3
98	4	4	1	1	4	1	4	4	4	3	4	0	3
99	3	3	1	4	0	0	4	4	4	0	4	0	3
100	4	0	0	0	4	1	4	0	4	0	4	0	4
101	3	3	4	4	4	3	4	4	3	3	3	4	0
102	0	0	4	4	4	1	4	4	4	4	4	0	0
103 [3]													
104	4	2	2	4	4	1	4	4	4	4	4	0	0
105	1	4	4	4	4	0	4	4	4	4	1	4	I
106	4	4	4	4	4	1	4	4	4	4	2	4	I
107	4	4	4	4	4	0	4	4	4	1	4	4	I
108	R	S	R	R	R	R	R	S	R	R	S	R	R
109	3	4	0	0	4	0	2	1	1	2	4	0	0
110	S	S	R	R	S	R	S	R	S	S	S	S	R
111	4	4	4	1	4	0	4	4	4	4	4	4	I
112	2	4	4	4	4	4	4	4	4	4	4	4	3
113	2	4	4	4	4	2	4	4	4	4	4	4	3

[1] Types and degrees of infection are represented by symbols as follows: I, immune (no macroscopic evidence of infection); 0, nearly immune (necrotic or chlorotic flecks or areas, but no uredia); 1, highly resistant (necrotic or chlorotic flecks or areas, some of which contain small uredia); 2, moderately resistant (necrotic or chlorotic flecks or areas, most of which contain small to midsized uredia); 3, moderately susceptible (chlorotic areas surrounding abundant, midsized uredia, no necrosis); 4, highly susceptible (no necrosis or chlorosis, uredia large and abundant); R, resistant; S, susceptible: x, mesothetic (infection heterogeneous and ill defined).

[2] The parasitic races listed were discovered or given numerical designations by the following: 1 to 33, Murphy; 34 to 37, Stakman, Levine, Christensen, and Isenbeck; 38 and 39, Peturson; 40, Waterhouse; 41, Murphy and Levine; 42 to 44, Brown; 45, Moore, Downie, and Murphy; 46, Murphy; 47, Waterhouse; 48 to 53, Kingsolver and Murphy; 54, Peturson; 55 and 56, Vallega; 57 to 95, Murphy; 96 to 100, Griffiths; 101, Rosen and Murphy; 102 and 104, Waterhouse; 105 to 107, Simons and Murphy; 108, Verma; 109, Finkner; 110, Silva; 111 to 113, Simons and Murphy.

[3] Reactions of race 103 are not tabulated because the race to which this number was given was later shown to be similar to a previously identified race.

331886—55——2

TABLE 2.—*Descriptive formulas for 112* [1] *races of crown rust identified on the old set of 13 differential oat varieties* [2]

Race	Resistant variety or varieties	Race	Resistant variety or varieties
29	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	6	1, 6, 12, 13
61	1, 2, 3, 4, 5, 6, 7, 8, 12, 13	57	1, 6, 13
80	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13	113	1, 6
65	1, 2, 3, 4, 5, 6, 10, 11, 12, 13	55	1, 13
62	1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 13	112	1
54	1, 2, 3, 4, 6, 7, 8, 12	46	2, 3, 4, 6, 7, 8, 12, 13
72	1, 2, 3, 4, 6, 7, 9, 10, 11, 12, 13	34	2, 3, 4, 6, 7, 8, 13
73	1, 2, 3, 4, 6, 7, 12, 13	100	2, 3, 4, 6, 8, 10, 12
92	1, 2, 3, 4, 6, 13	104	2, 3, 6, 12, 13
50	1, 2, 3, 4, 7, 12, 13	28	2, 4, 5, 6, 9, 12, 13
93	1, 2, 3, 6, 7, 13	4	2, 4, 6, (7), 8, 12, 13
94	1, 2, 3, 6, 11, 13	53	2, 4, 7, 12, 13
2	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	35	2, 5, 6, 9, 10, 11, 12
38	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12	77	2, 6, 12, 13
39	1, 2, 4, 5, 6, 7, 8, 9, 10, 12, 13	33	2, 6, (11), 13
44	1, 2, 4, 5, 6, 7, 9, 10, 11, 12	32	(2), (4), (5), 6, (7), (8), 10, (11), 12, 13
5	1, 2, 4, 6, 7, 8, 12, 13		
9	1, 2, 5, 6, 9, 10, 11, 12, 13	11	3, 4, 5, 6, 7, 12
76	1, 2, 5, 6, 9, 12, 13	109	3, 4, 6, 7, 8, 9, 10, 12, 13
21	1, 2, 5, 6, 12, 13	37	3, 4, 6, 7, 8, 10, 12, 13
86	1, 2, 6, 8, 12, 13	68	3, 4, 6, 7, 8, 13
102	1, 2, 6, 12, 13	7	3, 4, 6, 7, 8, 12, 13
41	1, 2, 12, 13	96	3, 4, 6, 7, 9, 10, 12
18	1, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13	40	3, 4, 6, 8, 12, 13
16	1, 3, 4, 5, 6, 7, 9, 10, 11, 12	110	3, 4, 6, 8, 13
108	1, 3, 4, 5, 6, 7, 9, 10, 12, 13	97	3, 4, 6, 10, 12
47	1, 3, 4, 6, 7, 8, 12, 13	85	3, 4, 6, 11, 12, 13
69	1, 3, 4, 6, 7, 8, 13	78	3, 4, 6, 12, 13
81	1, 3, 4, 6, 7, 12, 13	98	3, 4, 6, 12
87	1, 3, 4, 6, 8, 10, 11, 13	88	3, 4, 6, 13
48	1, 3, 4, 6, 8, 12, 13	99	3, 5, 6, 10, 12
49	1, 3, 4, 6, 12, 13	91	3, 5, 7, 13
90	1, 3, 4, 6, 13	12	3, 6, 8, 12, 13
52	1, 3, 4, 12, 13	95	3, 6, 13
58	1, 3, 5, 6, 7, 8, 12, 13	20	4, 6, 7, 8, 12, 13
82	1, 3, 6, 12, 13	26	4, 6, 7, 12, 13
19	1, 4, 5, 6, 7, 9, 10, 11, 12, 13	27	4, 6, 8, 10, 12, 13
64	1, 4, 5, 6, 7, 10, 11, 12, 13	25	4, 6, 8, 12, 13
63	1, 4, 5, 6, 7, 12, 13	31	(4), 6, (8), 12, 13
22	1, 4, 6, 7, 8, 12, 13	111	4, 6, 13
17	1, 4, 6, 7, 9, 10, 11, 12	10	5, 6, 7, 8, 12, 13
84	1, 4, 6, 7, 12, 13	36	5, 6, 9, 10, (11), 12
75	1, 4, 6, 10, 11, 12, 13	23	5, 6, 9, 11, 12, 13
83	1, 4, 6, 12, 13	13	5, 6, 10, 11, 12
3	1, 5, 6, 9, 10, 11, 12, 13	60	5, 6, 12, 13
24	1, 5, 6, 9, 10, 11, 12	74	6, 9, 10, 11, 12, 13
42	1, 5, 6, 9, 10, 12	79	6, 10, 12, 13
8	1, 5, 6, 9, 11, 12, 13	107	6, 10, 13
70	1, 5, 6, 9, 11, 12	43	6, 11, 12, 13
14	1, 5, 6, 10, 11, 12, 13	106	6, 11, 13
59	1, 5, 6, 12, 13	1	6, 12, 13
51	1, 6, 9, 10, 11, 12, 13	30	6, 12
67	1, 6, 9, 10, 12	45	6, 13
71	1, 6, 10, 11, 12, 13	89	6
66	1, 6, 10, 12, 13	56	12, 13
15	1, 6, 11, 12, 13	101	13
105	1, 6, 11, 13		

[1] See footnote 3, table 1.

[2] For names of varieties designated by the numbers tabulated, see table 1. Parentheses signify a mesothetic reaction (infection heterogeneous and ill defined).

MATERIALS AND METHODS

In the investigations reported here, which were made in 1950 and 1951, 6 oat varieties having the newer sources of resistance to crown rust were tested as differentials along with the standard set of 13 differential varieties. The names and C. I. numbers of the 19 varieties are given in table 3. Not only the standard differentials but the varieties Landhafer, Santa Fe, and Ukraine had been used as crown rust differentials in earlier investigations, reports on which are cited in the table. These 16 varieties represent the major taxonomic groups of the cultivated oats. Of the 3 other varieties, Trispernia came to the United States from Canada but was obtained by the Canadian investigators from Rumania; Bondvic was developed by Murphy at the Iowa Agricultural Experiment Station from an Anthony-Bond x Boone cross; and Saia was introduced into the United States from Canada but apparently originated in Brazil.

The 19 varieties were tested as 3 groups: (1) The standard 13 differential varieties; (2) a new set containing Anthony, Victoria, Appler, and Bond of the old set plus the new varieties Landhafer, Santa Fe, Ukraine, Trispernia, Bondvic, and (in 1951) Saia; and (3) the combined set of 13 old varieties plus 5 new ones in 1950 and 6 new ones in 1951. These groups, and the numeration of the varieties used throughout the remainder of the bulletin, are shown in table 4.

Collections of crown rust were obtained from plant pathologists, oat breeders, and others located at widely scattered points in the eastern half of the United States. Two collections were obtained from Mexico. In 1950, 290 cultures were used; in 1951, 381. Methods of inoculation, isolation, and testing used were similar to those described by Murphy (*7*).

RACES IDENTIFIED IN 1950

Because the variety Saia was not used in 1950, races characterized on the new and combined sets of differential varieties in 1950 cannot be compared directly with races so characterized in 1951 or with any other races that may later be identified on the complete new set of differentials. For this reason the 1950 data are presented here in summary form only. The complete 1950 data are contained in an unpublished thesis by the senior author.[11]

By use of the old set of differentials, 14 races were differentiated among collections made in 1950 (table 5); race 45 was the most common, accounting for 63.1 percent of the cultures. The relatively new race 101 was isolated from 2 collections made by I. M. Atkins at Weslaco, Tex., on Landhafer and an unknown variety. Race 111, which had not been described previously, was isolated 9 times. It resembled the common race 45 except that it could not parasitize Anthony.

By use of the new set of differential varieties minus Saia, 27 races were differentiated among collections made in 1950. Of this total, 16 were later found to correspond roughly to races identified by use of the complete new set in 1951.

[11] SIMONS, M. D. PHYSIOLOGIC SPECIALIZATION AND INHERITANCE OF RESISTANCE TO SPECIFIC RACES OF PUCCINIA CORONATA CORDA VAR. AVENAE F. & L. 1952. [Unpublished doctor's thesis. Copy on file Iowa State College Library, Ames.]

TABLE 3.—*Oat varieties tested as crown rust differentials*

No.	Variety	C. I. No.	Scientific name	Literature on use as a differential
1	Ruakura	2025	*Avena sativa*	Hoerner (*3*), Parson (*9*), Frenzel (*2*), Murphy (*7*), Peturson (*11*), Brown (*1*), Kingsolver.[1]
2	Green Russian	2890	do	Hoerner (*3*), Popp (*12*), Murphy (*7*), Peturson (*11*), Brown (*1*), Straib (*17*), Kingsolver.[1]
3	Hawkeye	2464	do	Murphy (*6*, *7*), Peturson (*11*), Brown (*1*), Kingsolver.[1]
4	Anthony	2143	do	Murphy (*6*, *7*), Peturson (*11*), Brown (*1*), Kingsolver.[1]
5	Sunrise	982	*A. byzantina*	Murphy (*7*), Peturson (*11*), Brown (*1*), Kingsolver.[1]
6	Victoria	2401	do	Murphy and Levine (*8*), Brown (*1*), Straib (*17*), Kingsolver.[1]
7	Green Mountain	1892	*A. sativa orientalis*	Parson (*9*), Frenzel (*2*), Murphy (*7*), Peturson (*11*), Brown (*1*), Straib (*17*).
8	White Tartar	551	do	Murphy (*7*), Peturson (*11*), Brown (*1*), Kingsolver.[1]
9	Red Rustproof (Appler)	1815	*A. byzantina*	Parson (*9*), Frenzel (*2*), Murphy (*6*, *7*), Peturson (*11*), Brown (*1*), Straib (*17*), Kingsolver.[1]
10	Sterisel	2981	do	Popp (*12*), Parson (*9*), Murphy (*7*), Peturson (*11*), Brown (*1*), Straib (*17*), Kingsolver.[1]
11	Belar	2760	do	Murphy (*6*, *7*), Peturson (*11*), Brown (*1*).
12	Bond	2733	do	Murphy and Levine (*8*), Brown (*1*).
13	Glabrota	2630	*A. strigosa*	Murphy (*7*), Peturson (*11*), Brown (*1*), Straib (*17*), Kingsolver.[1]
14	Landhafer	3522	*A. byzantina*	Straib (*17*), Kingsolver.[1]
15	Santa Fe	4519	do	Vallega (*18*).
16	Ukraine	3259	*A. sativa*	Kingsolver.[1]
17	Trispernia	4009	*A. byzantina*	
18	Bondvic	5401	*A. sativa*	
19	Saia	4639	*A. strigosa*	

[1] KINGSOLVER, C. H. DETERMINATION OF PARASITIC RACES IN PUCCINIA CORONATA AVENAE. 1939. [Unpublished master's thesis. Copy on file Iowa State College Library, Ames.]

TABLE 4.—*The 3 sets in which the 19 varieties were tested as differentials*

Old set		New set		Combined set	
No.	Variety	No.	Variety	No.	Variety
1	Ruakura	101	Anthony	1	Ruakura
2	Green Russian	102	Victoria	2	Green Russian
3	Hawkeye	103	Appler	3	Hawkeye
4	Anthony	104	Bond	4	Anthony
5	Sunrise	105	Landhafer	5	Sunrise
6	Victoria	106	Santa Fe	6	Victoria
7	Green Mountain	107	Ukraine	7	Green Mountain
8	White Tartar	108	Trispernia	8	White Tartar
9	Appler	109	Bondvic	9	Appler
10	Sterisel	110	Saia [1]	10	Sterisel
11	Belar			11	Belar
12	Bond			12	Bond
13	Glabrota			13	Glabrota
				14	Landhafer
				15	Santa Fe
				16	Ukraine
				17	Trispernia
				18	Bondvic
				19	Saia [1]

[1] Used in 1951 only.

TABLE 5.—*Races of crown rust identified on old set of 13 differential varieties in 1950 and 1951, and distribution of each among cultures used*

Race	1950 cultures		1951 cultures	
	Number	*Percent*	*Number*	*Percent*
1	9	3. 1	4	1. 1
6	0	0	3	. 8
15	0	0	1	. 3
45	183	63. 1	246	66. 1
55	0	0	5	1. 3
56	1	. 3	0	0
57	23	7. 9	22	5. 9
68	1	. 3	0	0
69	1	. 3	0	0
78	1	. 3	0	0
88	20	6. 9	1	. 3
89	1	. 3	5	1. 3
90	3	1. 0	0	0
91	2	. 7	0	0
95	34	11. 7	3	. 8
101	2	. 7	72	19. 4
105	0	0	2	. 5
106	0	0	1	. 3
107	0	0	4	1. 1
111	9	3. 1	1	. 3
112	0	0	1	. 3
113	0	0	1	. 3

The remaining 11 obviously were distinct from any of the 1951 races, regardless of how Saia would have reacted to them. These 11 races, however, have been left unnumbered because the reaction of Saia to them is unknown.

When the old set of 13 differentials and 5 of the new differentials were used as a single set of 18 varieties, greater diversification was evident; 43 separate races were differentiated among the same collections that, when tested on the old and new sets, had appeared to contain 14 and 27 races, respectively.

RACES IDENTIFIED IN 1951

Among 372 cultures from collections made in 1951, 16 races were differentiated by use of the old set of 13 differential varieties (table 5). Race 45 was by far the most prevalent. It accounted for 66.1 percent of the total number of cultures, in comparison with 63.1 percent of the cultures from collections made in 1950. Race 101, observed for the first time in 1949, was the second most prevalent race in 1951. It was identified 72 times, and thus accounted for 19.4 percent of all the cultures. This race parasitizes Victoria aggressively, while race 45 induces only very small pustules on Victoria. Race 55, closely related to race 101 in parasitic action, was identified 5 times.

Race 57 followed race 101 in order of prevalence. It was identified 22 times, and thus made up 5.9 percent of the cultures. Race 89, which attacked all 13 differential varieties except Victoria, was observed 5 times. Race 111, first found in 1950, was found once among the 1951 cultures.

Bond was resistant to only 8 of the 372 cultures, including 4 of race 1, 3 of race 6, and 1 of race 15.

Five races that had not been described before were observed. These were numbered 105, 106, 107, 112, and 113. Race 112 attacks Victoria and all other varieties of the old set except Ruakura. It differs sharply from races 55 and 101 in that it produces an infection of type 3 or 4 on Glabrota, whereas they ordinarily produce no macroscopic evidence of infection on this variety. Race 113 attacks Glabrota but not Victoria. Races 105, 106, and 107 are not of special interest, differing among themselves and from the other races by the reactions they induce on Ruakura, Sterisel, and Belar. Race 107 was isolated 4 times, and race 105 twice. Each of the other new races was identified only once.

When 381 cultures from collections made in 1951 were tested on the new set of 10 differential varieties, 27 races were differentiated and were given numbers beginning with 201 (table 6). Race 202 was the most prevalent one; isolates identified as of this race made up 35.2 percent of the total. Race 203 was the second most prevalent, with 70 isolates, or 18.4 percent of the total. It differed from 202 only by its ability to attack Ukraine. Races having the ability to parasitize Victoria totaled 7. The most common of these was 213, which occurred 53 times. The other "Victoria races" were 216, with 23 isolates; 215, with 3 isolates; 217 and 218, with 2 isolates each; and 214, which was identified once.

By use of the combined set of 19 differential varieties, 44 races (table 7) were differentiated among the 1951 collections. The most common of these, comprising 32.7 percent of the total number of cultures, was that identified as race 45 on the old set and as race 202 on the new set. The second most common race, comprising 15.9

percent of all the cultures, was that identified as race 45 or 203. The third was that identified as 101 or 213.

TABLE 6.—*Racial distribution of 1951 cultures according to tests on old and new sets of differentials, respectively, by geographic source of collections*

OLD SET OF 13 DIFFERENTIALS

Race	Cultures, by geographic origin of collections								
	North Central States		Northeastern States		Southern States		Mexico	Total	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Number*	*Percent*
1	3	1. 1	0	0	1	1. 1	0	4	1. 1
6	3	1. 1	0	0	0	0	0	3	. 8
15	1	. 4	0	0	0	0	0	1	. 3
45	170	65. 1	8	44. 4	66	72. 5	2	246	66. 1
55	3	1. 1	2	11. 1	0	0	0	5	1. 3
57	15	5. 7	4	22. 2	3	3. 3	0	22	5. 9
88	0	0	0	0	1	1. 1	0	1	. 3
89	5	1. 9	0	0	0	0	0	5	1. 3
95	0	0	0	0	3	3. 3	0	3	. 8
101	53	20. 3	2	11. 1	17	18. 7	0	72	19. 4
105	1	. 4	1	5. 5	0	0	0	2	. 5
106	0	0	1	5. 5	0	0	0	1	. 3
107	4	1. 5	0	0	0	0	0	4	1. 1
111	1	. 4	0	0	0	0	0	1	. 3
112	1	. 4	0	0	0	0	0	1	. 3
113	1	. 4	0	0	0	0	0	1	. 3
Total	261	100. 0	18	100. 0	91	100. 0	2	372	100. 0
Races per geographic source number	13	------	6	------	6	------	1	16	------

NEW SET OF 10 DIFFERENTIALS

201	1	0. 4	0	0	1	1. 2	0	2	0. 5
202	106	39. 0	7	31. 8	19	22. 4	2	134	35. 2
203	45	16. 5	6	27. 3	19	22. 4	0	70	18. 4
204	0	0	0	0	1	1. 2	0	1	. 3
205	1	. 4	1	4. 5	0	0	0	2	. 5
206	13	4. 8	2	9. 1	3	3. 5	0	18	4. 7
207	13	4. 8	1	4. 5	0	0	0	14	3. 7
208	0	0	0	0	1	1. 2	0	1	. 3
211	2	. 7	0	0	0	0	0	2	. 5
213	46	16. 9	1	4. 5	6	7. 1	0	53	13. 9
214	1	. 4	0	0	0	0	0	1	. 3
215	3	1. 1	0	0	0	0	0	3	. 8
216	15	5. 5	3	13. 6	5	5. 9	0	23	6. 0
217	1	. 4	1	4. 5	0	0	0	2	. 5
218	0	0	0	0	2	2. 4	0	2	. 5
219	0	0	0	0	4	4. 7	0	4	1. 0
220	5	1. 8	0	0	9	10. 6	0	14	3. 7
221	5	1. 8	0	0	2	2. 4	0	7	1. 8
222	1	. 4	0	0	11	12. 9	0	12	3. 1
223	0	0	0	0	1	1. 2	0	1	. 3

TABLE 6.—*Racial distribution of 1951 cultures according to tests on old and new sets of differentials, respectively, by geographic source of collections*—Continued

NEW SET OF 10 DIFFERENTIALS—Continued

Race	Cultures, by geographic origin of collections								
	North Central States		Northeastern States		Southern States		Mexico	Total	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Number*	*Percent*
224	4	1. 5	0	0	0	0	0	4	1. 0
225	1	. 4	0	0	0	0	0	1	. 3
227	1	. 4	0	0	0	0	0	1	. 3
233	2	. 7	0	0	1	1. 2	0	3	. 8
237	2	. 7	0	0	0	0	0	2	. 5
241	3	1. 1	0	0	0	0	0	3	. 8
242	1	. 4	0	0	0	0	0	1	. 3
Total	272	100. 0	22	100. 0	85	100. 0	2	381	100. 0
Races per geographic source number	22	------	8	------	15	------	1	27	------

In general, finer distinctions were made with the new set of differentials than with the old (table 7). When the cultures characterized as of old race 45 were identified on the new differentials, for example, they were found to represent 11 different races—one-fourth of the total number of races differentiated by the combined set. The most prevalent of these 11 races, defined as race 202 on the new set, comprised nearly half the group. Use of the new set did not always result in finer distinctions, however; in some cases a group of cultures identified on it as of a single race were of several different races according to tests on the old set. For example, the cultures identified as of race 202, most common of the new races, were identified as of 5 different races when tested on the old set. The most common of these, which accounted for 87 percent of the group, was race 45.

The cultures tested in 1951 represented substantial numbers of collections made in each of two regions of the United States—the North Central States and the South (table 6). On the basis of tests on the standard differentials, a comparison was made between the cultures representing these two regions, respectively, as to prevalence of each of the more common races. It appeared that there was little if any significant difference between the two groups of cultures in this respect. For example, race 45 accounted for 65.1 percent of the cultures from the North Central States and 72.5 percent of those from the South, and race 101 accounted for 20.3 percent of the cultures from the North Central States and 18.7 percent of those from the South. Certain of the new races, on the other hand, were relatively more common among the cultures from one of these regions than among those from the other.

TABLE 7.—*Relative distribution of cultures tested in 1951 among races differentiated on old and new sets* [1] *of differential varieties, respectively*

Race differentiated on new set	Distribution of cultures with reference to corresponding race or races differentiated on old set	Race differentiated on old set	Distribution of cultures with reference to corresponding race or races differentiated on new set	Cultures
	Percent		*Percent*	*Number*
201	100. 0	111	100. 0	1
202	87. 0	45	48. 4	121
	7. 9	57	52. 4	11
	1. 4	89	66. 7	2
	2. 2	95	75. 0	3
	1. 4	107	50. 0	2
203	85. 5	45	23. 6	59
	8. 7	57	28. 6	6
	1. 4	89	33. 3	1
	2. 9	107	50. 0	2
	1. 4	113	100. 0	1
204	100. 0	88	100. 0	1
205	50. 0	57	4. 8	1
	50. 0	105	50. 0	1
206	94. 5	45	7. 2	18
	5. 3	57	4. 8	1
207	76. 5	45	5. 2	13
	11. 2	57	9. 5	2
	5. 9	105	50. 0	1
	5. 9	106	100. 0	1
208	100. 0	95	25. 1	1
213	4. 4	55	66. 7	2
	95. 5	101	95. 5	43
214	100. 0	101	1. 4	1
215	100. 0	101	4. 3	3
216	5. 9	55	33. 3	1
	88. 2	101	21. 4	15
	5. 9	112	100. 0	1
217	100. 0	101	2. 9	2
218	100. 0	101	2. 9	2
219	100. 0	101	5. 7	4
220	100. 0	45	5. 2	13
221	100. 0	45	2. 8	7
222	100. 0	45	4. 8	12
223	100. 0	45	. 4	1
224	100. 0	45	1. 6	4
225	100. 0	6	33. 3	1
227	50. 0	6	33. 3	1
	50. 0	15	100. 0	1
233	100. 0	1	75. 0	3
237	50. 0	1	25. 0	1
	50. 0	6	33. 3	1
241	100. 0	45	. 4	1
242	100. 0	45	. 4	1

[1] Each of the 44 different combinations of races identified on the old and new sets represents one of the 44 races identified on the combined set.

Races 202 and 213 were much more common among the cultures from the North Central States than among those from the South, and race 203 was somewhat more common among those from the South.

COMPARATIVE MERITS OF SETS OF DIFFERENTIALS

Relative efficiency of the 3 sets of differentials was estimated on the basis of their reactions to the 370 cultures identified on the combined set of 19 differential varieties in 1951. Of the several different procedures by which relative efficiencies might be computed, two were used (table 8). In both, the efficiency of the standard set of differentials was arbitrarily rated 100 and that of each of the other sets was computed in relation to this value.

TABLE 8.—*Relative efficiencies of 3 sets of differential varieties in identifying cultures from collections of crown rust made in 1951*

Item	Old set	New set	Combined set
Varieties—number	13	10	19
Races differentiated—number	16	26	44
Rating of efficiency:[1]			
By method 1 [2]	100	162. 5	275. 0
By method 2 [3]	100	211. 2	188. 2

[1] The efficiency of the old set was arbitrarily rated 100, and that of each of the other sets was computed in relation to this value.

[2] Efficiency was rated on the basis of number of races differentiated.

[3] Efficiency was rated on the basis of ratio of number of races differentiated to number of varieties used as differentials.

The most obvious measure of efficiency was the total number of races differentiated with each set. By using the old set, a total of 16 races could be differentiated among the 370 cultures; by using the new set, 26 races; by using the combined set, 44 races. On this basis the combined set was the most efficient, differentiating almost 3 times as many races as the old set and about 70 percent more than the new set. The relative efficiency values were 100, 162.5, and 275.

This procedure ignores differences in numbers of varieties in the three sets. There is justification on practical grounds for taking such differences into account, as more labor is involved in identifying a given number of collections on a set containing 19 varieties, for example, than in identifying them on a set containing only 10 varieties. The old set differentiated, on an average, a little more than 1 race per variety. With the ratio for the old set taken as 100, comparable figures for the new and combined sets were 211.2 and 188.2, respectively. On this basis the new set is clearly superior to the combined set.

In deciding what set of differential varieties should be recommended over the others, not only the efficiency of each set but other factors had to be considered. One of these was the fact that information gained by differentiating races of crown rust is used primarily by persons interested in oat breeding and oat pathology. Such persons are concerned with the prevalence of groups of races that attack varieties used as sources of resistance in existing commercial varieties of oats or used in producing new commercial varieties.

Among the standard 13 differential varieties, 9 are no longer of value from a commercial or breed-

ing standpoint. These are Ruakura, Green Russian, Hawkeye, Sunrise, Green Mountain, White Tartar, Sterisel, Belar, and Glabrota. Races differentiated by these varieties are now of little interest to the oat breeder. Use of these varieties as differentials could be discontinued for this reason alone. All these 9 varieties except Glabrota have other disadvantages. Green Russian and Sunrise were susceptible to all cultures of crown rust tested in 1950 and 1951, and Green Mountain, White Tartar, Sterisel, and Belar were susceptible to most of these cultures. Consequently these 6 varieties have little value as differentials. The Sunrise variety is particularly objectionable because of its strong tendency to exhibit extreme necrosis when subjected to high temperatures in the humidity chamber. The reactions of some of the 9 varieties—particularly Ruakura—to certain cultures varied somewhat according to environmental conditions (*10*).

On the basis of the facts stated, it is recommended that the old set and the combined set of differentials not be used further in differentiating crown rust races.

Of the 10 varieties that compose the new set of differentials, all have certain advantages. Landhafer, Santa Fe, Trispernia, and Ukraine are good differential varieties. The first two of these rather uniformly exhibited a well-defined 0 reaction to most of the cultures, not greatly affected by environmental variation. Ukraine was either clearly resistant or clearly susceptible to nearly all the cultures. The reaction of Trispernia to some cultures was affected by temperature variations; resistance of this variety tended to break down at higher temperatures. These four varieties are all valuable as sources of resistance to many races of crown rust.

Victoria, Red Rustproof (Appler), and Bond, which represent the genetic sources of resistance to crown rust in oat varieties currently grown over much of the United States and Canada, exhibited fairly clear-cut susceptible or resistant reactions to most cultures. Furthermore, together with Anthony, they constitute a link with the old set of differentials. Inclusion of these four "older" varieties will enable investigators to establish relationships between old and new races, at least to a limited extent. For example, so far as reaction of these 4 varieties is concerned a group of races including 202, 203, 205, and others may be said to correspond to a group of old races including 45, 57, 95, and others.

Bondvic, a variety recently developed in Iowa, carries a type of resistance to crown rust not found in other varieties. However, its reaction to some cultures is intermediate between susceptible and resistant. Saia, which exhibits clear-cut reactions, is highly resistant to many races of crown rust and also is resistant to stem rust.

In view of the individual advantages of these 10 varieties and their efficiency as a set in identifying isolates of crown rust, it is suggested that they be used in the future for all crown rust race identification.

REACTIONS OF RECOMMENDED DIFFERENTIALS TO RACES IDENTIFIED ON THEM THROUGH 1951

While the study reported here was in progress, other investigators were testing the same new set of 10 crown rust differentials used in it. Peturson, in correspondence with the authors, described 20 races characterized by reactions of these differentials. Silva (*15*) described 24 such races. In some instances the same races were discovered independently by different investigators. The complete series of crown rust races that had been identified on the new set of differential varieties by the end of 1951 included 59 races numbered 201 to 259, the discoverers and codiscoverers of which were as follows:

Race or races	*Discoverer or codiscoverers*
202	Peturson; Silva; Simons and Murphy.
201, 203, 237	Peturson; Simons and Murphy.
205, 216, 221, 223, 225, 233.	Silva; Simons and Murphy.
236, 238	Peturson; Silva.
204, 206, 207, 208, 213, 214, 215, 217, 218, 219, 220, 222, 224, 227, 241, 242, 258, 259.	Simons and Murphy.
209, 210, 211, 212, 226, 228, 229, 230, 231, 232, 234, 235, 239, 240.	Peturson.
243 to 257	Silva.

Average reactions of the new set of 10 differential varieties, in the seedling stage, to these 59 races are presented in table 9. To facilitate rapid identification of the races, descriptive formulas listing the varieties resistant to each are presented in table 10.

TABLE 9.—*Average reactions* [1] *of new set of 10 differential varieties of oats, in the seedling stage, to races 201 to 259 of crown rust* [2]

Race	101 Anthony	102 Victoria	103 Appler	104 Bond	105 Landhafer	106 Santa Fe	107 Ukraine	108 Trispernia	109 Bondvic	110 Saia
201	R	R	S	S	R	R	R	R	R	R
202	S	R	S	S	R	R	R	R	R	R
203	S	R	S	S	R	R	S	R	R	R
204	R	R	S	S	R	R	S	R	S	S
205	S	R	S	S	R	R	R	R	R	S
206	S	R	S	S	R	R	R	R	S	R
207	S	R	S	S	R	R	S	R	S	R
208	S	R	S	S	R	R	S	R	S	S
209	R	R	R	S	R	R	R	R	R	R
210	R	R	R	S	R	R	S	R	R	R
211	R	R	S	S	R	R	S	R	R	R
212	S	R	R	S	R	R	R	R	R	R
213	S	S	S	S	R	R	R	R	R	R
214	S	S	S	S	R	R	R	R	R	S
215	S	S	S	S	R	R	R	R	S	R
216	S	S	S	S	R	R	S	R	R	R

See footnotes at end of table.

TABLE 9.—*Average reactions* [1] *of new set of 10 differential varieties of oats, in the seedling stage, to races 201 to 259 of crown rust* [2]—Continued

Race	101 Anthony	102 Victoria	103 Appler	104 Bond	105 Landhafer	106 Santa Fe	107 Ukraine	108 Trispernia	109 Bondvic	110 Saia
217	S	S	S	S	R	R	S	R	S	R
218	S	S	S	S	R	R	R	S	R	R
219	S	S	S	S	R	R	S	S	R	R
220	S	R	S	S	R	R	R	S	R	R
221	S	R	S	S	R	R	R	S	S	R
222	S	R	S	S	R	R	S	S	R	R
223	S	R	S	S	R	R	S	S	R	S
224	S	R	S	S	R	R	S	S	S	R
225	S	R	S	R	R	R	R	S	R	R
226	S	R	S	R	R	R	S	R	R	R
227	S	R	S	R	R	R	S	R	R	S
228	R	R	R	R	R	R	S	R	R	R
229	R	R	R	R	R	R	S	R	R	S
230	R	R	S	R	R	R	S	R	R	R
231	S	R	R	R	R	R	S	R	R	R
232	S	R	R	R	R	R	S	R	R	S
233	S	R	S	R	R	R	R	R	S	R
234	R	R	R	R	R	R	R	R	R	S
235	S	R	R	R	R	R	R	R	R	S
236	S	R	S	R	R	R	R	R	R	S
237	S	R	S	R	R	R	R	R	R	R
238	R	R	S	R	R	R	R	R	R	R
239	R	R	R	R	R	R	R	R	R	R
240	S	R	R	R	R	R	R	R	R	R
241	S	R	S	S	R	R	S	R	R	S
242	S	R	S	S	R	R	R	R	S	S
243	S	R	S	R	R	R	R	S	S	S
244	S	R	S	R	R	R	R	S	S	R
245	R	R	S	S	R	R	R	S	Int	R
246	R	R	S	R	R	R	R	S	Int	S
247	R	R	S	S	R	R	S	S	S	R
248	S	R	S	R	R	R	S	S	S	S
249	R	R	S	R	R	R	R	S	S	R
250	S	R	S	S	R	R	R	S	R	S
251	R	R	S	S	R	R	R	R	R	S
252	S	R	S	S	R	R	R	S	S	S
253	S	S	S	S	R	R	R	S	S	R
254	R	R	S	R	R	R	S	S	Int	R
255	S	R	S	R	R	R	R	S	R	S
256	S	R	S	S	S	R	R	R	R	S
257	S	R	S	S	R	Int	R	R	R	R
258	S	S	S	R	R	R	R	R	R	R
259	S	S	S	R	R	R	S	R	R	R

[1] R=resistant (infection types I, 0, 1, and 2); S=susceptible (infection types 3 and 4); Int=intermediate between resistant and susceptible. Infection types are defined in footnote 1 of table 1.

[2] Discoverers of races 201 to 259 are listed on p. 18.

TABLE 10.—*Descriptive formulas for 59 races of crown rust identified on new set of 10 differential oat varieties*

Race	Resistant varieties [1]	Race	Resistant varieties [1]
239	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	227	2, 4, 5, 6, 8, 9
234	1, 2, 3, 4, 5, 6, 7, 8, 9	248	2, 4, 5, 6
228	1, 2, 3, 4, 5, 6, 8, 9, 10	202	2, 5, 6, 7, 8, 9, 10
229	1, 2, 3, 4, 5, 6, 8, 9	257	2, 5, (6), 7, 8, 9, 10
209	1, 2, 3, 5, 6, 7, 8, 9, 10	205	2, 5, 6, 7, 8, 9
210	1, 2, 3, 5, 6, 8, 9, 10	206	2, 5, 6, 7, 8, 10
238	1, 2, 4, 5, 6, 7, 8, 9, 10	242	2, 5, 6, 7, 8
246	1, 2, 4, 5, 6, 7, (9)	220	2, 5, 6, 7, 9, 10
249	1, 2, 4, 5, 6, 7, 10	250	2, 5, 6, 7, 9
230	1, 2, 4, 5, 6, 8, 9, 10	221	2, 5, 6, 7, 10
254	1, 2, 4, 5, 6, (9), 10	252	2, 5, 6, 7
201	1, 2, 5, 6, 7, 8, 9, 10	203	2, 5, 6, 8, 9, 10
251	1, 2, 5, 6, 7, 8, 9	241	2, 5, 6, 8, 9
245	1, 2, 5, 6, 7, (9), 10	207	2, 5, 6, 8, 10
211	1, 2, 5, 6, 8, 9, 10	208	2, 5, 6, 8
247	1, 2, 5, 6, 10	222	2, 5, 6, 9, 10
204	1, 2, 5, 6, 8	223	2, 5, 6, 9
240	2, 3, 4, 5, 6, 7, 8, 9, 10	224	2, 5, 6, 10
235	2, 3, 4, 5, 6, 7, 8, 9	256	2, 6, 7, 8, 9
231	2, 3, 4, 5, 6, 8, 9, 10	258	4, 5, 6, 7, 8, 9, 10
232	2, 3, 4, 5, 6, 8, 9	259	4, 5, 6, 8, 9, 10
212	2, 3, 5, 6, 7, 8, 9, 10	213	5, 6, 7, 8, 9, 10
237	2, 4, 5, 6, 7, 8, 9, 10	214	5, 6, 7, 8, 9
236	2, 4, 5, 6, 7, 8, 9	215	5, 6, 7, 8, 10
233	2, 4, 5, 6, 7, 8, 10	218	5, 6, 7, 9, 10
225	2, 4, 5, 6, 7, 9, 10	253	5, 6, 7, 10
255	2, 4, 5, 6, 7, 9	216	5, 6, 8, 9, 10
244	2, 4, 5, 6, 7, 10	217	5, 6, 8, 10
243	2, 4, 5, 6, 7	219	5, 6, 9, 10
226	2, 4, 5, 6, 8, 9, 10		

[1] Numbers in this column refer to the differential varieties listed in table 9. The numbers associated with varietal names in table 9 have been coded here by subtracting 100 from each. Parentheses signify intermediate reaction.

SUMMARY

The fungus *Puccinia coronata* Cda. var. *avenae* Fraser & Led., commonly called crown rust, causes the most serious disease of oats in the eastern half of the United States. The set of 13 varieties of oats chosen in 1935–36 as standard differentials for races of this rust has now lost much of its usefulness, because new or formerly unimportant races of the rust have become prevalent. With a view to finding a more serviceable set of crown rust differentials, these and other oat varieties were tested in 1950 and 1951 on cultures from collections made at widely scattered points in the North Central, Northeastern, and Southern States. The varieties tested were grouped in 3 sets: (1) The standard 13 differentials—Ruakura, Green Russian, Hawkeye, Anthony, Sunrise, Victoria, Green Mountain, White Tartar, Appler, Sterisel, Belar, Bond, and Glabrota; (2) a new set containing Anthony, Victoria, Appler, and Bond of the old set plus Landhafer, Santa Fe, Ukraine, Trispernia, Bondvic, and, in 1951,

Saia; and (3) the combined series of old and new varieties.

In 1950, tests on the old set of differentials led to differentiation of 14 races, of which the most common was race 45. A race not previously described was numbered 111. By use of the new set, 27 races were differentiated; by use of the combined set, 43.

In 1951, 16 races were differentiated on the old set of differentials. Race 45 again was the most prevalent form, being even more common than in 1950. Race 101, observed for the first time in 1949, was the second most prevalent, comprising almost 20 percent of the total number of isolates identified. Five new races were described and were numbered 105, 106, 107, 112, and 113. Race 112 parasitized all varieties of the old set except Ruakura. By use of the new set, 27 races were differentiated. These were given numbers beginning with 201. Race 202 was the most prevalent, comprising 35.2 percent of all the isolates. By use of the combined set, 44 races were differentiated. The most common of these was the one identified as race 45 on the old set and as race 202 on the new set.

Relative efficiencies of the three sets in 1951 were calculated on the basis of the 370 cultures tested on the combined set. Within this series of cultures the old set differentiated 16 races; the new set, 26 races; and the combined set, 44 races. According to total number of races identified, the new set had a relative efficiency value of 162.5 and the combined set a value of 275 on a scale on which the efficiency of the old set was arbitrarily rated 100. According to ratio of number of races identified to number of varieties composing a set, the new set was rated 211.2 and the combined set 188.2 on such a scale.

Aside from ratings of the relative efficiency of the three sets of differential varieties, the characteristics of the individual varieties composing each set and the value of the information obtained by use of each set were considered with regard to possible bearing on the solution of problems encountered in oat breeding and pathological investigations. With these factors in mind it is recommended that the new set of 10 varieties used in 1951 be used henceforth to identify races of crown rust.

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