PHYSIOLOGIC RACES OF USTILAGO LEVIS AND U. AVENAE ON RED OATS[1]

By GEORGE M. REED, *Curator, Brooklyn Botanic Garden,* and T. R. STANTON, *Senior Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

The results of a study of smut specimens for the determination of specialized races of *Ustilago avenae* (Pers.) Jens. and *U. levis* (Kell. and Sw.) Magn. are presented in the following pages. This paper also reports the identification of a hitherto unknown physiologic race of *U. levis* which attacks Fulghum oats.

REVIEW OF LITERATURE

Extensive data on physiologic races of the fungi that cause loose and covered smuts on oats have been published by Reed (*4, 5, 6*)[2] and by Sampson (*7, 8*). Several distinct races of both species have been identified. Among the races of *Ustilago avenae* two of particular interest attack the Fulghum and Red Rustproof varieties. The Fulghum race of *U. avenae* is capable of severely smutting Fulghum and the closely related Kanota and Frazier strains. In addition, several varieties of common oats, such as Bicknell, Black Diamond, Canadian, and Victor, are severely attacked. Hull-less or naked oats and the wild species *Avena barbata* Brot. also are very susceptible. On the other hand, strains of the Red Rustproof type are extremely resistant to this particular race of *U. avenae.*

The physiologic race of *Ustilago avenae* which attacks Red Rustproof also is highly specialized. It produces a large percentage of smutted plants on Red Rustproof and the related Nortex. On Fulghum and its strains, however, it gives essentially negative results. Apparently there is only one variety of the *Avena sativa* group, namely Canadian, that is susceptible. Hull-less oats also are extremely resistant. It is an interesting fact, however, that *A. barbata* is completely susceptible.

Hitherto no race of *Ustilago levis* has been known to attack seriously Fulghum and Red Rustproof oats. Reed (*6*) has shown that Fulghum occasionally may be slightly smutted by a form of *U. levis* from Missouri, but the percentage of smutted plants is never very high. Occasional plants of Red Rustproof, apparently smutted with this same race, also have been found.

IMPORTANCE OF FULGHUM AND RED RUSTPROOF OATS

Variously named strains of the Fulghum and Red Rustproof varieties of oats are grown extensively in the southern half of the United

[1] Received for publication July 17, 1931; issued March, 1932. The investigations here reported were conducted by the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, in cooperation with the Brooklyn Botanic Garden, Brooklyn, N. Y. Contribution No. 62 Brooklyn Botanic Garden.

[2] Reference is made by number (italic) to Literature Cited, p. 152.

States. In the Cotton Belt they are grown almost exclusively, and mostly from fall seeding. In the region immediately to the north of the Cotton Belt they are important spring-sown varieties, especially Fulghum and its strain Kanota. Fulghum is now most extensively grown in Missouri, Kansas, and Oklahoma, where it has largely replaced the Burt and Red Rustproof varieties. The last named is not altogether satisfactory for spring seeding, owing to its later maturity. Prior to the development of Fulghum, early varieties of common oats such as Kherson and Sixty-Day also were grown to some extent in this area, with generally unsatisfactory results, owing to poor adaptation. Stanton and Coffman (*9, 10*) have made available information on the importance and distribution of the Fulghum and Red Rustproof varieties.

MATERIALS AND METHODS

In the spring of 1929 the junior writer collected samples of oat smut in various parts of the South and forwarded them to the senior writer at the Brooklyn Botanic Garden. An identification number was assigned to each collection, by which each is hereafter designated. Ten of these collections have been tested for their physiologic specialization. The oat varieties used as testers or differential hosts were Canadian (seed No.[3] 119), Victor (seed No. 126), Fulghum (seed No. 129), Red Rustproof (seed No. 131), and Navarro (Ferguson Navarro; seed No. 939, C. I.[4] No. 966).

The inoculations were made by the method described by Reed (*6*). All tests were made under greenhouse conditions at the Brooklyn Botanic Garden.

EXPERIMENTAL DATA

The reaction of the five differential hosts to *Ustilago levis* collected from the Fulghum variety, is shown in Table 1. Collection numbers and geographic origin are likewise shown.

TABLE 1.—*Reaction of the five differential hosts to Ustilago levis collected from Fulghum oats*

Variety	Collection No. 16; Athens, Ga.			Collection No. 18; Clemson College, S. C.		
	Plants	Infected		Plants	Infected	
	Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
Canadian	13	13	100.0	17	17	100.0
Victor	19	16	84.2	19	19	100.0
Fulghum	19	18	94.7	19	15	78.9
Red Rustproof	19	0	0	18	0	0
Navarro	19	0	0	19	0	0

Collections Nos. 16 and 18 proved to be typical of the covered smut. Both produced high percentages of smut on Fulghum. Collection No. 16 produced smut on 18 of the 19 plants, or 94.7 per cent, and collection No. 18 produced smut on 15 of 19 plants, or 78.9 per cent. Collection No. 16 gave 100 per cent infection on Canadian and 84.2

[3] Seed numbers designate special strains of the varieties propagated and maintained by the senior writer.
[4] C. I. refers to accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

per cent on Victor, while collection No. 18 produced 100 per cent infection on both of these varieties. Red Rustproof and Navarro proved highly resistant to both collections.

The reaction of the five differential hosts to *Ustilago avenae* collected from the Norton, Kanota, and Frazier varieties (collections Nos. 8, 48, and 56, respectively) is shown in Table 2. The geographic origin of each collection is also shown.

TABLE 2.—*Reaction of the five differential hosts to Ustilago avenae collected from Norton, Kanota, and Frazier oats*

Variety	Collection No. 8; A. and M. College, Miss.			Collection No. 48; Near Newton, Kan.			Collection No. 56; Lawton, Okla.		
	Plants	Infected		Plants	Infected		Plants	Infected	
	Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
Canadian	19	19	100.0	19	17	89.4	20	20	100.0
Victor	20	8	40.0	20	11	55.0	18	17	94.4
Fulghum	20	20	100.0	20	20	100.0	20	20	100.0
Red Rustproof	19	0	0	19	0	0	20	0	0
Navarro	20	0	0	20	0	0	20	0	0

Collection Nos. 8, 48, and 56 (Table 2) correspond quite closely in reaction to the Fulghum race of *Ustilago levis* shown in Table 1. All three collections gave 100 per cent infection on the Fulghum variety. Very high percentages of smut also were obtained on Canadian. The Victor variety gave somewhat variable results, the percentage of smutted plants ranging from 40.0 to 94.4. The results with Red Rustproof and Navarro were entirely negative. These data are in harmony with those reported by Reed (*5*, *6*) for the physiologic race of *U. avenae* on Fulghum oats.

The reaction of the five differential hosts to *Ustilago avenae* collected from the Ferguson No. 922, Nicholson Hundred Bushel, and Nortex strains of the Red Rustproof variety (collections 25, 53, and 57, respectively) is shown in Table 3. The geographic origin of each collection is given in the table.

TABLE 3.—*Reaction of the five differential hosts to Ustilago avenae collected from Ferguson No. 922, Nicholson Hundred Bushel, and Nortex oats*

Variety	Collection No. 25; Denton, Tex.			Collection No. 53; Stillwater, Okla.			Collection No. 57; Lawton, Okla.		
	Plants	Infected		Plants	Infected		Plants	Infected	
	Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
Canadian	19	16	84.2	20	19	95.0	19	17	89.4
Victor				20	2	10.0	20	1	5.0
Fulghum	20	0	0	20	0	0	20	6	30.0
Red Rustproof	20	15	75.0	20	14	70.0	20	19	95.0
Navarro	20	0	0	19	0	0	19	0	0

Collections Nos. 25, 53, and 57 are very similar to, if not identical with, the previously described form of *Ustilago avenae* obtained from Red Rustproof oats (*5*, *6*). The three named strains of Red Rustproof from which the collections were made are typical of the Red

Rustproof variety. Comparatively high percentages of smutted plants were obtained with all three collections on Red Rustproof, the percentages ranging from 70.0 to 95.0. A somewhat higher percentage of smut (from 84.2 to 95.0 per cent) was secured with the variety Canadian. A few smutted plants of Victor were obtained with two of the collections, but no smutted plants whatever were obtained on Navarro. Fulghum gave negative results with two of the collections, but with No. 57, 30 per cent of the plants, or 6 out of 20, were smutted. There is a possibility in this case that the original collection of smut was a mixture of the Red Rustproof and Fulghum races. Further experiments are necessary to determine whether this is the case.

Two additional collections from Cowra No. 22 and Colburt (C. I. No. 2019) also have given interesting results. The reaction of the five differential hosts to *Ustilago avenae* collected from these varieties (collections Nos. 46 and 59, respectively) is shown in Table 4. The geographic sources of the collections are shown in the table.

TABLE 4.—*Reaction of the five differential hosts to Ustilago avenae collected from Cowra No. 22 and Colburt oats*

Variety	Collection No. 46; Experiment, Ga.			Collection No. 59; Lawton, Okla.		
	Plants	Infected		Plants	Infected	
	Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
Canadian	19	19	100	19	19	100
Victor	19	19	100	19	19	100
Fulghum	20	3	15	20	0	0
Red Rustproof	20	0	0	20	0	0
Navarro	20	0	0	20	0	0

Collection No. 46, from the Cowra No. 22 variety, gave 100 per cent infection on both Canadian and Victor. The Fulghum variety showed 15 per cent of smutted plants, 3 out of a total of 20 being smutted. Negative results were secured with Red Rustproof and Navarro. In its ability to infect Fulghum slightly and to infect Canadian and Victor heavily, this collection is allied to the Missouri race of *Ustilago avenae*. The remaining collection, No. 59, gave 100 per cent infection on the two varieties, Canadian and Victor, while entirely negative results were secured with Fulghum, Red Rustproof, and Navarro.

DISCUSSION

The most interesting feature of the results of this study is the identification of a definite specialized race of *Ustilago levis*, hitherto unknown, which attacks the Fulghum variety of oats. (Fig. 1.) The two collections, Nos. 16 and 18, are typical of this species, and both show a high degree of virulence for this type of oat. As yet no similar race of covered smut capable of infecting the Red Rustproof variety has been demonstrated. It is, however, very probable that such a form or race is actually in existence and will be identified sooner or later.

Further experiments are in progress to determine more definitely the extent of the specialization of the new collections. A large number

of varieties of oats, representing different types, have been inoculated in order to determine their susceptibility.

Some further discussion of the relationship of such varieties as Norton, Cowra No. 22, and Colburt to Red Rustproof and Fulghum in connection with their reaction to certain of the 10 smut collections reported in this paper seems desirable.

It was to be expected that Norton would show high susceptibility to *Ustilago avenae* collected from Fulghum. Norton was originated as a selection from a cross between Fulghum (Coker Fulghum strain No. 3) and an unnamed gray oat (R–F–3) with side panicle, which was obtained as an individual plant from a field of mixed Red Rust-

FIGURE 1.—Smutted panicles of Fulghum oats; A and B infected with *Ustilago levis*, C and D with *U. avenae*. The contrast between the two smuts is very evident

proof by George J. Wilds, jr., in 1918. The cross was made a few years later by J. B. Norton in the breeding nurseries of Coker's Pedigreed Seed Co., Hartsville, S. C.

The close relationship of Norton to the Kanota and Frazier strains of Fulghum is demonstrated by the results presented in Table 2. On the other hand, relative to plant characters, Norton resembles common rather than red oats. These facts undoubtedly furnish further evidence that the inheritance of susceptibility or resistance to smut in oats is not linked with morphological characters.

The Cowra No. 22 (also known as Quandong) variety was introduced from Australia. According to Pridham (*2*, *3*) it was originated as a selection from Ruakura on the Cowra Experiment Farm, New South Wales. The latter variety was developed from a plant varia-

tion from the Red Algerian (Argentina), a variety belonging to *Avena byzantina* C. Koch, morphologically similar to the well-known Red Rustproof oat of the South. Ruakura, however, usually has been classified as belonging to *A. sativa* L. Cowra No. 22 is similar to Ruakura in that it is more or less intermediate in type between the varieties of *A. sativa* and *A. byzantina*. In this connection it is of interest to point out that differential hosts belonging to both of these groups reacted to the smut collected on Cowra No. 22. (Table 4.)

The origin of the Colburt variety has been reported by Stanton, Griffee, and Etheridge (*11*) and by Coffman (*1*). It was developed as a plant selection from Burt, a red oat, at Akron, Colo. However, Colburt is an early black common oat (*Avena sativa*), morphologically similar to Monarch. Colburt is a very uniform variety and evidently represents a mechanical mixture rather than a plant variation from Burt. As a consequence, Colburt probably is not closely related to such varieties as Fulghum, Red Rustproof, and Navarro. The data shown in Table 4 indicate specialization of the race of smut collected on Colburt to varieties belonging to *A. sativa*. It is very probable, therefore, that this smut was introduced from Akron, Colo., to Lawton, Okla., on Colburt itself.

SUMMARY

Results of a study of a collection of smut specimens, mostly of red oats, for the determination of specialized races of *Ustilago avenae* and *U. levis* are reported.

The identification of a hitherto unknown specialized race of covered smut which attacks Fulghum oats is demonstrated.

As red oats are grown extensively and in some sections almost exclusively in the southern half of the United States, the identification of a specialized race of covered smut attacking Fulghum may be of considerable economic importance.

Of the 10 collections studied, 2 were typical of *Ustilago levis*, and both showed a high degree of virulence in attacking Fulghum. As yet no similar race of covered smut capable of infecting the closely allied Red Rustproof variety has been identified.

LITERATURE CITED

(1) Coffman, F. A.
1925. Experiments with cereals at the Akron (Colo.) field station in the 15-year period, 1908 to 1922, inclusive. U. S. Dept. Agr. Bul. 1287, 63 p., illus.

(2) Pridham, J. T.
1921. Varieties of oats tested in New South Wales. Agr. Gaz. N. S. Wales 32: 249–252.

(3) ———
1921. Descriptions of new varieties of cereals. Agr. Gaz. N. S. Wales 32: 699–703, illus.

(4) Reed, G. M.
1924. Physiologic races of oat smuts. Amer. Jour. Bot. 11: 483–492, illus.

(5) ———
1927. Further evidence of physiologic races of oat smuts. Mycologia 19: 21–28.

(6) ———
1929. New physiologic races of the oat smuts. Bul. Torrey Bot. Club 56: 449–470.

(7) SAMPSON, K.
1925. SOME INFECTION EXPERIMENTS WITH LOOSE AND COVERED SMUTS OF OATS WHICH INDICATE THE EXISTENCE IN THEM OF BIOLOGICAL SPECIES. Ann. Appl. Biol. 12: 314–325, illus.
(8) ———
1929. THE BIOLOGY OF OAT SMUTS. II. VARIETAL RESISTANCE. Ann. Appl. Biol. 16: 65–85, illus.
(9) STANTON, T. R., and COFFMAN, F. A.
1929. SPRING-SOWN RED OATS. U. S. Dept. Agr. Farmers' Bul. 1583, 18 p., illus.
(10) ——— and COFFMAN, F. A.
1930. FALL-SOWN OAT PRODUCTION. U. S. Dept. Agr. Farmers' Bul. 1640, 20 p., illus.
(11) ——— GRIFFEE, F., and ETHERIDGE, W. C.
1926. REGISTRATION OF VARIETIES AND STRAINS OF OATS. Jour. Amer. Soc. Agron. 18: 935–947.