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BIOLOGIC FORMS OF PUCCINIA GRAMINIS ON VARIETIES OF AVENA SPP.[1]

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Puccinia graminis tritici Erikss. and Henn., which originally was considered as a single biologic form, has been shown by Stakman and Piemeisel (*11*),[3] Levine and Stakman (*5*), Melchers and Parker (*7*), Stakman, Levine, and Leach (*10*), and Stakman and Levine (*9*) actually to consist of many forms which differ in their parasitic action on certain varieties of *Triticum* spp. Hoerner (*4*) showed that there is a similar specialization of *Puccinia coronata* Cda. on varieties of *Avena* spp. and Mains and Jackson (*6*) found two biologic forms of *P. triticina* Erikss. on varieties of wheat. It seemed quite likely, therefore, that *P. graminis avenae* Erikss. and Henn. might also consist of several biologic forms. Experiments, therefore, were begun in the fall of 1918 to ascertain whether this was true.

It is obvious that one of the most direct methods for ascertaining whether there are biologic forms of rust, with different parasitic capabilities on varieties of cereals, is to find forms of rust capable of infecting varieties ordinarily practically immune from described rust forms, or vice versa. As a result of preliminary studies on *Puccinia graminis avenae* it was found that Victory (both C. I. No. 1145 [4] and Minn. 514), Improved Ligowa (Minn. 281), Minota (Minn. 512), and many other varieties of oats were extremely susceptible to the rust strains [5] used, while White Tartar (White Russian) (Minn. 339 and two pure-line selections made by the section of plant pathology at the Iowa Experiment Station and designated as Rust Nursery Row No. 101½ and 102½), was quite resistant. The writers, therefore, began collecting uredinial material of *P. graminis* Pers. on oats from as many different localities as possible, in this and other countries.

Since the fall of 1918, more than 100 collections of *P. graminis* on oats have been obtained from 21 States of the United States, from two Provinces in Canada, and from one State in Mexico. Seventy-six of the collections have been cultured in the greenhouse of the section of plant pathology at University Farm, St. Paul, Minn. Many of these were used for inoculating seedlings of about 70 different varieties and selections

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[2] The writers are indebted for rust material to Prof. W. P. Fraser, pathologist in charge of Cereal Disease Investigations, Dominion Laboratory of Plant Pathology, in cooperation with the University of Saskatchewan, Saskatoon, Sask, Canada; to Prof. Wallace Butler, of San Antonio, Tex.; to Mr. G. F. Puttick, of the Department of Agriculture of the Union of South Africa; and to Mr. Fred Griffee, assistant plant breeder, Department of Agriculture, University of Minnesota. They also are indebted to other Federal and State pathologists for collections of rust.

Dr. H. K. Hayes, plant breeder, Department of Agriculture, University of Minnesota and collaborator of the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, made valuable suggestions for which the authors wish to express their appreciation.

[3] Reference is made by number (italic) to "Literature cited," p. 1017–1018.

[4] C. I.=Cereal investigations accession number.

[5] The term "strain" is used only to designate a culture of rust from a single collection.

of oats, belonging to 6 different species of the genus Avena, namely: *A. brevis* Roth., *A. nuda* L., *A. sativa* L., *A. orientalis* L., *A. sterilis* L., and *A. strigosa* Schreb.

It was found that definite preliminary results were likely to be obtained by using only three varieties of oats, viz: Victory, White Tartar (White Russian) and Monarch Selection (of Etheridge). All collections were run to Victory and White Tartar (White Russian). Victory was completely susceptible to all of the strains tried, White Tartar was very highly resistant to most of them, while Monarch Selection, which was inoculated only with the collections made in 1921 and 1922, was extremely susceptible to some of these collections and practically immune from others. Attempts then were made to find forms of stem rust which would infect the White Tartar variety heavily. This was achieved with rust material procured from Europe and Africa.

Victory was completely susceptible to, White Tartar very resistant to, and Monarch Selection (of Etheridge) practically immune from, a form collected by Mr. Fred Griffee at St. Paul, Minn. This is designated hereafter as Form I.

A form of rust collected by Prof. Wallace Butler at San Marcos, Tex., infected Victory normally, developed only lightly on White Tartar, but produced large, vigorous uredinia on Monarch Selection. These results were confirmed by repeated inoculations, and clearly indicated the existence of a second biologic form of *Puccinia graminis avenae*, as it was capable of infecting Monarch Selection normally, which the form collected by Mr. Griffee could not infect. This is designated as Form II.

A rust strain sent by Mr. G. F. Puttick from Potchefstroom, Union of South Africa, infected Victory normally, White Tartar moderately, and Monarch Selection normally. This undoubtedly was a third form and is hereafter called Form III.

Finally, Stakman found a form at Upsala, Sweden, which infected White Tartar just as heavily as it did Victory and Monarch Selection. This, then, was a fourth form,[6] designated as Form IV.

Table I summarizes the action of these four forms on the varieties of oats which served as the differential hosts.

It is quite evident from Table I that Form I (Pl. 2, A) infects Victory normally, but develops only lightly on White Tartar (White Russian) and exceedingly lightly on Monarch Selection. Form II (Pl. 2, B) infects Victory and Monarch Selection heavily, but attacks White Tartar only lightly. Form III (Pl. 3, A), like Form II, attacks Victory and Monarch Selection very heavily and in addition attacks White Tartar moderately. Form IV (Pl. 3, B) infects all three varieties very heavily. Repeated inoculations have been made and the same results have been obtained consistently.

Two different forms were isolated from a single collection several times. In some cases the X type of infection described for wheat rust (*9, p. 5*) also developed on oats. Several strains produced this X type of infection on Monarch Selection, thus indicating the probable existence of a fifth biologic form which infects Victory very heavily, White Tartar only lightly and Monarch Selection heterogeneously (Pl. 4). There are now known, therefore, at least four, and probably five, biologic forms of *Puccinia graminis avenae* which produce different reactions on certain varieties of *Avena* spp.

[6] Proper disposition is being made of the spore material of the South African and Swedish forms, as they have not yet been found in the United States.

TABLE I.—*Results of inoculating three differential varieties of Avena spp., with four biologic forms of Puccinia graminis avenae*

Biologic Form No.	Place of collection.	Summary of inoculation results.					
		Victory (C. I. No. 1145).		White Tartar (Minn. 339).		Monarch Selection (of Etheridge).	
		Number of trials[a]	Character of infection.	Number of trials.	Character of infection.	Number of trials.	Character of infection.
I	St. Paul, Minn.	19	Normal, heavy infection. Uredinia large, numerous and coalescing.	8	Infection light. Uredinia usually small and scattered. Hypersensitiveness (sharp chlorosis to definite necrosis) ordinarily present.	6	Infection exceedingly light. Uredinia, when present, minute, scattered and surrounded by very sharply defined necrotic areas. Distinct hypersensitive flecks also occur quite frequently.
II	San Marcos, Tex.	16	.....do.....	8	.....do.....	6	Normal, heavy infection. Uredinia large, coalescent and numerous.
III	Potchefstroom, South Africa.	7	.....do.....	5	Infection moderate. Uredinia medium in size and only slightly confluent. True hypersentitiveness absent, but light chlorotic areas usually present.	3	Do.
IV	Upsala, Sweden.	2	.....do.....	2	Normal, heavy infection. Uredinia large, many, and confluent.	2	Do.

[a] From 10 to 15 plants were inoculated in each trial.

These newly discovered biologic forms are quite as distinct as are those of *P. graminis* on wheat varieties (*12*). The inoculations were made on seedlings in the greenhouse, but, as a result of previous work, it is safe to conclude that the reaction of seedlings to rust forms is a fairly accurate index of the reaction of older plants. It usually is more difficult to obtain infection on older plants than it is on seedlings, but this apparently is due very largely to the fact that the film of water necessary for spore germination and entrance of germ tubes through the stomata, is not easily maintained on old plants. However, when this difficulty is overcome, by atomizing the plants several times a day, infection occurs normally.

The new forms apparently are constant. Repeated inoculations and cross inoculations have been made with most of them and the results have been consistent. There are variations, of course, in the intensity of rust development when the environmental conditions are unfavorable for the development of host or parasite or both. When light intensity is low, and when the temperature is either too high or too low, the rust develops subnormally. If the host plants are weakened by poor growing conditions, by mildew, root rots, or other factors, the rust usually does not develop well. This variation, however, does not indicate any change in the genotypic constitution of the rust forms, but is only the temporary result of environment. In order to draw accurate conclusions regarding the parasitic behavior of biologic forms it is necessary to grow the host plants and the rust fungus within the range of environmental conditions in

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