TECHNICAL BULLETIN 8 JULY 1922

The University of Minnesota
Agricultural Experiment Station

The Determination of Biologic Forms of Puccinia Graminis on Triticum Spp.

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THE DETERMINATION OF BIOLOGIC FORMS OF PUCCINIA GRAMINIS ON TRITICUM SPP.[1]

By E. C. Stakman and M. N. Levine

It has been shown (1, 2, 3, 4)[2] that *Puccinia graminis tritici* (Pers.) Erikss, and Henn. in reality consists of several biologic forms which can be recognized by their action on different varieties of wheat (*Triticum vulgare, T. durum, T. compactum*), Emmer (*T. dicoccum*) and Einkorn (*T. monococcum*). Stakman, Levine and Leach (3) stated that they had found about a dozen such forms. Thirty-seven are now known and a method has been developed for their identification.

Since there have been a considerable number of inquiries regarding the methods used, and since the complete results cannot be published for some time, it seems desirable to publish, in advance of a more detailed presentation of the results, a description of the methods employed and a summary of the behavior of the biologic forms discovered.

All of the known forms can be identified by their parasitic action on the twelve "differential hosts" which are listed in Table 1. These varieties of *Triticum spp.* were selected from a much greater number which were originally used. It is likely that many more forms could be recognized if the proper combination of differential hosts were employed.

TABLE I

List of Differential Hosts Used in Identifying Biologic Forms of Stem Rust of Wheat

Triticum compactum
- Little Club, C. I.* No. 4066

Triticum vulgare
- Marquis, C. I. No. 3641 (Minn. 1239)
- Kanred, C. I. No. 5146 (Kans. 2401)
- Kota, C. I. No. 5878 (N.D. 10003)

Triticum durum
- Arnautka, C. I. No. 4072 (S.D. 150)
- Mindum, C. I. No. 5296 (Minn. 470)
- Arnautka (Speltz Marz), C. I. No. 6236 (Minn. 337)
- Kubanka, C. I. No. 2094
- Acme, C. I. No. 5284 (S.D. 284)

Triticum monococcum
- Einkorn, C. I. No. 2433

Triticum dicoccum
- White Spring Emmer, C. I. No. 3686 (Minn. 1165)
- Khapli, C. I. No. 4013

* C. I.=Cereal Investigations accession number.

[1] Coöperative investigations between the Agricultural Experiment Station of the University of Minnesota and the Bureau of Plant Industry of the United States Department of Agriculture.

[2] Reference is made by number to literature citations.

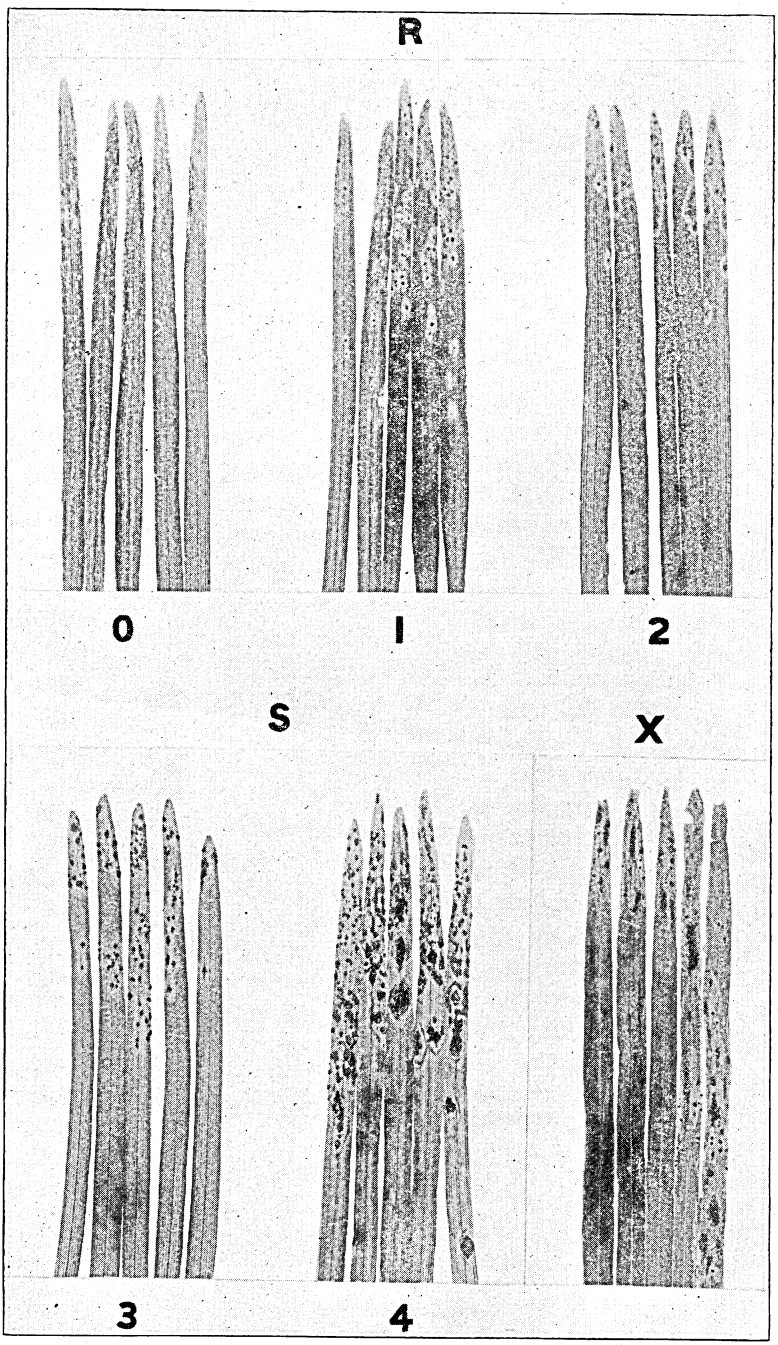

Fig. 1. Different types of infection produced by biologic forms of *Puccinia graminis* on various differential hosts of *Triticum spp.* Class R, indicating resistance, includes types 0, 1 and 2; class S, designating susceptibility, includes types 3 and 4; class X, representing the heterogeneous type of infection, has no subdivisions.

The varieties listed in Table I are inoculated in the usual manner and incubated for 48 hours. While single-spore isolations should be made for very careful work, it is not necessary for the purpose of a general survey. Whenever possible all of the differential hosts should be inoculated at the same time and kept under the same environmental conditions subsequently. The best results will be obtained by keeping the inoculated plants under optimum conditions for the normal development of the rust. An abundant supply of sunlight is highly essential.

The types or classes of infection are indicated by arabic numerals from 0 to 4 in order of severity of infection, 0 indicating practical immunity and 4 complete susceptibility. Fluctuations within a class have been designated by plus and minus signs. In addition to the five types above mentioned, there is a sixth type which is represented by x. On the same plant various degrees of infection may occur, apparently ranging from 1 to 4. It has been shown that this is quite characteristic of the action of some biologic forms on certain varieties and it should be distinguished clearly from mixed infections due to the presence of two or more biologic forms on the same plant. The various types of infection will be clear from Plate I and Table II. Cross inoculations are sometimes necessary before a final determination can be made.

TABLE II

EXPLANATION OF SYMBOLS USED TO INDICATE TYPES AND DEGREES OF INFECTION PRODUCED BY BIOLOGIC FORMS OF PUCCINIA GRAMINIS ON VARIETIES OF WHEAT

Types of Infection

0 — IMMUNE
No uredinia developed; hypersensitive flecks usually present, but sometimes there is apparent absolutely no trace of mycelial invasion in the host tissues

1 — VERY RESISTANT
Uredinia minute and isolated; surrounded by sharp, contniuous, hypersensitive, necrotic areas

2 — MODERATELY RESISTANT
Uredinia isolated and small to medium in size; hypersensitive areas present in the form of necrotic halos or circles; pustules often in green, but slightly chlorotic, islands

3 — MODERATELY SUSCEPTIBLE
Uredinia medium in size; coalescence infrequent; development of rust somewhat subnormal; true hypersensitiveness absent; chlorotic areas, however, may be present

4 — VERY SUSCEPTIBLE
Uredinia large, numerous and confluent; true hypersensitiveness entirely absent, but chlorosis may be present when cultural conditions are unfavorable

x — HETEROGENEOUS
Uredenia very variable, apparently including all types and degrees of infection on the same blade; no mechanical separation possible; on reinoculation small uredinia may produce large ones, and vice versa. Infection ill defined

Degrees of Infection

(=) — TRACE
Uredinia very few in number and covering a limited surface; development of rust generally poor and decidedly subnormal

(—) — SLIGHT
Rust development below normal, but somewhat better than "trace"

(±) — MODERATE
Variation in rust development from "slight" to "considerable"; when infection is uniform but only medium in quantity the symbol is omitted

(+) — CONSIDERABLE
Infection better than normal; uredinia fairly numerous and scattered

(++) — ABUNDANT
Luxuriant development of rust; uredinia very many, covering large area of affected host

Miscellaneous Symbols

(;) — Hypersensitive flecks
(.) — Necrotic lesions

After the type and degree of infection on the differential hosts have been recorded, it is relatively easy to determine the biologic form by the use of the dichotomous key given in Table III. Plants on which the degree of attack is from 0 to 2 are considered resistant and those on which the degree is 3 or 4 are considered susceptible. Those on which the heterogeneous type of infection develops are, of course, in the x class. In the key only these major differences are recognized. The actual determination of biologic forms, therefore, is made by determining only whether the differential hosts are susceptible or resistant or whether they react in the peculiar manner designated by x.

TABLE III

ANALYTICAL KEY TO BIOLOGIC FORMS OF PUCCINIA GRAMINIS WITHIN THE GENUS TRITICUM

Infection homogeneous on all differential hosts
- Marquis resistant (R)
  - Kanred resistant
    - Kota resistant
      - Arnautka resistant
        - Kubanka resistant II
        - Kubanka susceptible
          - Einkorn resistant XXVII
          - Einkorn susceptible XXIII
      - Arnautka susceptible
        - Mindum resistant VI
        - Mindum susceptible
          - Kubanka resistant IV
          - Kubanka susceptible
            - Einkorn resistant XVI
            - Einkorn suceptible XIV
    - Kota susceptible
      - Mindum resistant XXVIII
      - Mindum susceptible XIX
  - Kanred susceptible
    - Arnautka resistant
      - Kubanka resistant VII
      - Kubanka susceptible XXXIII
    - Arnautka susceptible X
- Marquis susceptible (S)
  - Kanred resistant
    - Kota resistant XXIV
    - Kota susceptible
      - Arnautka resistant I
      - Arnautka susceptible
        - Mindum resistant XXVI
        - Mindum susceptible
          - Kubanka resistant
            - Emmer resistant V
            - Emmer susceptible VIII

Kubanka susceptible
Einkorn resistant XXI
Einkorn susceptible
Emmer resistant XVII
Emmer susceptible IX
Kanred susceptible
Kota resistant XXXV
Kota susceptible
Arnautka resistant
Mindum resistant
Kubanka resistant III
Kubanka susceptible
Acme resistant XX
Acme susceptible XVIII
Mindum susceptible
Speltz Marz resistant.....XXV
Speltz Marz susceptible.....XXII
Arnautka susceptible
Mindum resistant XII
Mindum susceptible
Kubanka resistant XIII
Kubanka susceptible
Einkorn resistant XXXIV
Einkorn susceptible
Emmer resistant XI
Emmer susceptible XV
Infection heterogeneous on some differential hosts
Marquis susceptible
Kanred resistant
Kota susceptible
Mindum indeterminate (X)
Emmer resistant XXIX
Emmer susceptible XXX
Mindum susceptible
Kubanka indeterminate XXXVII
Kanred susceptible
Kota resistant
Mindum indeterminate XXXI
Kota susceptible
Mindum resistant
Kubanka indeterminate XXXVI
Mindum indeterminate XXXII

The use of the key is very simple. For instance, Marquis is either resistant or susceptible. Assuming it is susceptible it then is necessary to know how Kanred reacts. If Kanred is resistant and Arnautka is also, then it is Form 1; but if Arnautka is susceptible, then the reaction of Mindum must be known, etc. It will be noted that neither Little Club nor Khapli appears in the key. This is because Little Club is susceptible to all known forms and Khapli is highly resistant to all of them.

When the form has been run down by the key, it is necessary to check up with the known action of each form as indicated in Table IV. If the infection capabilities agree with those indicated for the form, the identification is complete; if they do not, then either the form is undescribed or there may be a mixture of forms and it becomes necessary to separate them.

TABLE IV

VARIATIONS AND CONSTANTS IN REACTION OF DIFFERENTIAL HOSTS OF WHEAT TO BIOLOGIC FORMS OF STEM RUST

Biologic forms	Ranges and means of infection																					
	*Ltl. Club		Marquis		Kanred		Kota		Arnautka		Mindum		#Ent. Marz		Kubanka		Acme		Einkorn		Emmer		Khapli	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
I.....	3+ 4++	4	3+ 4++	4-	0 0;	0	3- 4+	3+	0. 1	1=	0 2+	1	0. 1+	1=	3- 4	3+	3 4	3+	3- 3+	3	0 1	0;	0 1+	1 =
II.....	4= 4+	4	1= 2++	2=	0 2+	2=	0 2	2=	0 1+	1-	0 2+	1	0 1+	1=	0 2	1+	3- 4+	3+	3= 4	3+	0; 1	1-	0 1	0;
III.....	3+ 4++	4	3+ 4++	4-	3= 4+	4=	3= 4	3+	0 1+	1=	0 2++	1=	0 2+	1-	0 2	1+	3= 4++	3+	3= 4	3+	0 2-	1=	0 1++	0;
IV.....	4 4+	4+	1 2++	2-	0 2+	1-	1 2	2=	3+ 4	4=	3 4	3+	3 4	3+	0; 2++	2	3 4+	3+	3- 4	3+	0. 1+	1=	0 1	1=
V.....	3+ 4++	4	3 4+	4-	0 2	0;	3= 3++	3	3 4	4=	3 4	3++	3- 4	3+	0; 2++	1++	3= 4	3+	3 3+	3	0 1-	0;	0 1-	0.
VI.....	4 4+	4	0; 2+	2	0 1-	1=	0 1	0;	3 4	3+	0; 2-	2=	1 2=	2=	1= 2+	1	3 4+	3+	3 4	3	0 0.	0.	0 1	0;
VII.....	3+ 4++	4	0 2++	2=	3- 4+	3+	0 1+	1=	0. 1	1=	0 2	1++	0 2	1-	0 2	1	3 4-	3++	3= 3	3-	0 2	1	0 1+	1-
VIII.....	3+ 4++	4	3++ 4+	4	0 0;	0.	3= 4	4-	3+ 4	4=	3 4	3++	3 4	4=	0 0;	0.	3- 3+	3	3 3+	3	3++ 4	4	0 1-	0;
IX.....	3+ 4++	4	3 4++	4-	0 0;	0	3= 4	3++	3- 4++	4-	3 4+	4=	3- 4++	4=	3- 4+	4=	3= 4+	3++	3- 4	3+	3- 4+	4=	0 1+	1-
X.....	3+ 4++	4+	1- 2++	2-	3 4-	3++	1= 2	2	3++ 4	4	3 4++	4	4- 4+	4	3 4	3++	3+ 4	4-	3- 3+	3+	0; 1-	1=	0; 1-	1=
XI.....	3 4++	4-	3+ 4+	4=	3 4	3++	3= 4-	3+	3= 4	4=	3= 4	4=	3 4	4=	3= 4+	3++	3- 4	3++	3 4	3	0 1+	1=	0 1	1=
XII.....	3+ 4++	4+	3+ 4+	4-	3 4	4=	3- 4	3+	3+ 4	4=	0. 2+	1	0. 2++	1++	0; 2++	1++	3- 4++	3++	3- 4	3+	0. 1	1=	0 1	0;
XIII.....	3 4+	4	3+ 4	4-	3 4	3++	3= 4+	3++	3 4	4=	3- 4	3++	3 4	3++	1 2+	2-	3- 4	3++	3- 4=	3	0; 2	1	0 1	1=
XIV.....	3- 4+	4+	1= 2++	2-	0 2+	1-	0 2+	1++	3- 4	3++	3 4+	3++	3 4+	3++	3 4	3++	3= 4	3++	3- 3+	3	0. 1+	1=	0 1-	0:
XV.....	3 4++	4	3 4+	4-	3 4	4=	3 4	3++	3 4+	4=	3- 4	4=	3- 4	4=	3- 4	3++	3 4	3++	3 4=	3+	3 4	4=	0 1+	1=
XVI.....	3- 4++	4-	1 2	2=	0 0.	0	1= 1+	1	3- 4	3++	3= 4-	3+	3 4	3++	3 3++	3+	3+ 4	4=	0 1-	1=	0; 1-	1=	0; 1++	1

XVII....	3+	4++	4	3-	4++	4-	0	1=	0.	3=	4	3+	3=	4++	4=	3-	4++	4=	3-	4+	4=	3-	4+	3++	3=	4	3++	3=	4	3	0	1+	1=	0	1+	1=
XVIII....	3+	4++	4	3	4+	4-	3-	4+	4=	3=	4	3++	0.	2+	1	0	2	1=	0	2++	1-	3-	4+	3++	3-	4	3++	3=	3++	3	0	2	1-	0	1++	1=
XIX.....	3+	4++	4	1-	2++	2-	0	2	0;	3=	4	3-	3=	4+	4=	3	4+	4=	3-	4	4=	3-	4+	3++	3-	4	3++	3=	4	3	0	1+	0;	0	1	1=
XX.....	3+	4++	4	3-	4++	4=	3-	4	4=	3++	4	4=	0;	2	1++	0.	2	1-	0	2	1++	3=	4	3++	0;	2++	1++	3+	3++	3+	0;	1=	1=	0;	1	1-
XXI.....	3+	4++	4	3+	4+	4	0	0;	0	3=	4-	3++	3++	4+	4-	3++	4++	4-	3+	4++	4-	3	4+	4=	3-	4	3++	0;	1+	1=	0.	1	0;	0	1	1=
XXII.....	3+	4+	4+	4	4++	4+	3+	4	4	3	3+	3	0;	1	1	3++	4+	4	3	4	4-	0;	1+	0.	3	3++	3+	3	3+	3	0	2	1-	0	0;	0.
XXIII...	3+	4++	4	1	2+	2	0	2+	1-	0;	1	1=	0;	2-	1	0	1	1=	0;	1+	1-	3=	3+	3+	3	4	3++	3-	3+	3	0;	1-	0;	0	1-	0;
XXIV.....	3+	4++	4	3	4+	4=	0	2	0;	0	2+	2=	3	4	4=	3-	4	4=	3-	4	4=	3-	4	3++	3-	4	3+	3=	3+	3	0.	1	1=	0	1+	0;
XXV.....	3+	4	4	3+	4	4	3	3+	3+	3=	3+	3	0;	1+	1-	3=	3+	3	0.	1	1=	3	3+	3	3=	4	3++	3-	3	3	0;	1-	1=	1=	1	1-
XXVI....	3	4++	4	4-	4	4	0	0;	0;	3-	3+	3	4=	4	4-	0;	1+	1=	3	4	3++	0;	1	1=	3+	4-	4=	3-	3	3	0;	1	1-	1	1+	1+
XXVII...	3	4+	4=	1	2++	2	0	0;	0	0	0;	0.	0	1	1=	0;	2-	1	0;	1+	1-	3	4	4=	3	4	3++	0	1	1=	3-	4+	4=	0.	2+	1+
XXVIII..	3+	4	4	0;	2++	2	0	0;	0.	3-	3+	3	4=	4-	4-	0	1	1	3	4	4=	3	4=	3	3-	3+	3	3	3+	3	0.	1	1=	0	0.	0.
XXIX....	4-	4++	4	3+	4+	4-	0	0;	0	3=	4-	3	X;	4+	X+	X=	4+	X±	X-	4+	X+	X-	4	X	X-	4	X+	3-	4	3	0;	2+	1-	0	2	1-
XXX.....	4-	4+	4	4-	4+	4	0	0;	0.	3-	4+	3+	X	4+	X+	X-	X+	X±	X	4-	X+	X-	X+	X	X+	4	X+	3-	4-	3+	3	4	4=	0;	2=	1
XXXI....	4	4++	4+	4-	4	4	3+	4	3+	1+	2++	2-	0;	X+	X-	0;	X+	X+	X	X+	X±	X-	X	X	X+	3	X+	3	3+	3+	0;	1	1-	0;	1=	1
XXXII...	4-	4++	4	3	4+	4=	3	4	4=	3=	4	3+	X-	4	X+	X-	4	X±	X-	4	X±	1+	X+	X	X-	4	X+	3=	4	3	0	1	1=	0	2-	1-
XXXIII..	4=	4++	4+	0;	2++	2	3	4+	4	0	2++	1+	0;	1-	1=	0;	1	1-	0;	1+	1	3-	4+	4=	3	4	3++	3-	3	3	0;	1	1-	0;	1	1
XXXIV...	4	4+	4+	4	4++	4-	3+	4+	4-	3++	4-	4=	3++	4++	4	3-	4+	4=	3-	4+	4=	3-	4+	4=	3	4=	3++	0;	1++	1=	0	0;	0;	0;	1	1=
XXXV....	4=	4	4	3	4	4=	3	3+	3+	0	0;	0;	0;	1=	1=	0;	1+	1-	0;	1=	1=	3-	3+	3+	3	4-	3++	3-	3	3	0	0;	0;	1-	1	1
XXXVI...	4	4+	4	4=	4+	4	4=	4	4-	3++	4	3++	0;	1	1=	0;	1	1=	0	0;	0;	X-	X+	X	3-	4	3++	3	3+	3	0;	1-	0;	0;	1	1-
XXXVII..	4	4+	4	3++	4+	4-	0	0;	0	3=	4-	3++	3+	4+	4=	3+	4	4=	3++	4+	4=	X-	X+	X	3-	3++	3-	3=	3+	3	0;	1	1=	0;	1	1-

* Little Club

\# Speltz Marz

It is not always possible to distinguish easily between infections due to a mixture of forms and that infection caused by forms producing an x reaction on certain varieties. Cross inoculations and inoculations made from the different types of uredinia only can be relied upon in such cases.

The methods described can naturally be modified to meet the requirements of individual investigators, but it seems likely that preliminary indications at least can be obtained by the use of the differential hosts listed in Table 1.

A complete summary of the results to date will be published later.

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