

JOURNAL OF AGRICULTURAL RESEARCH

CONTENTS

	Page
New Physiologic Races of Flax Rust (Key No. G-1162) - - - -	575
H. H. FLOR	
The Effect of Several Chemicals on the Swelling and the Crushing Strength of Wood (Key No. Minn.-114) - - - -	593
HARVEY D. ERICKSON and LOUIS W. REES	
The Influence of Temperature, Moisture, and Food upon the Develop- ment and Survival of the Saw-Toothed Grain Beetle (Key No. Minn.- 115) - - - -	605
EDWARD L. THOMAS and HAROLD H. SHEPARD	
Retention by Soils of the Nitrogen of Various Compounds as Shown by Subsequent Plant Response (Key No. Calif.-112) - - - -	617
JOHN P. CONRAD	
The Resistance of Progeny of Katahdin Potatoes to Viroses (Key No. Wash.-34) - - - -	631
LEON K. JONES, C. L. VINCENT, and EARL F. BURK	



ISSUED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE
WITH THE COOPERATION OF THE ASSOCIATION
OF LAND-GRANT COLLEGES AND
UNIVERSITIES

JOINT COMMITTEE ON POLICY AND MANUSCRIPTS

FOR THE UNITED STATES DEPARTMENT OF AGRICULTURE

H. G. KNIGHT, CHAIRMAN
Chief, Bureau of Chemistry and Soils

JOHN W. ROBERTS
*Principal Pathologist, Bureau of Plant
Industry*

BENJAMIN SCHWARTZ
*Principal Zoologist, Chief, Zoological Division,
Bureau of Animal Industry*

FOR THE ASSOCIATION OF LAND-GRANT COLLEGES AND UNIVERSITIES

S. W. FLETCHER
*Director of Research, Pennsylvania Agricultural
Experiment Station*

C. E. LADD
*Director, New York (Cornell) Agricultural
Experiment Station*

V. R. GARDNER
*Director, Michigan Agricultural Experiment
Station*

EDITORIAL SUPERVISION

M. C. MERRILL

Chief of Publications, United States Department of Agriculture

Articles for publication in the Journal must bear the formal approval of the chief of the department bureau, or of the director of the experiment station from which the paper emanates. Each manuscript must be accompanied by a statement that it has been read and approved by one or more persons (named) familiar with the subject. The data as represented by tables, graphs, summaries, and conclusions must be approved from the statistical viewpoint by someone (named) competent to judge. All computations should be verified.

Station manuscripts and correspondence concerning them should be addressed to S. W. Fletcher, Director of Research, Pennsylvania Agricultural Experiment Station, State College, Pa.

Published on the 1st and 15th of each month. This volume will consist of 12 numbers and the contents and index.

Subscription price:

Entire Journal: Domestic, \$3.25 a year (2 volumes)

Foreign, \$4.75 a year (2 volumes)

Single numbers: Domestic, 15 cents

Foreign, 20 cents

Articles appearing in the Journal are printed separately and can be obtained by purchase at 5 cents a copy domestic; 8 cents foreign. If separates are desired in quantity, they should be ordered at the time the manuscript is sent to the printer. Address all correspondence regarding subscriptions and purchase of numbers and separates to the Superintendent of Documents, Government Printing Office, Washington, D. C.

NEW PHYSIOLOGIC RACES OF FLAX RUST¹

By H. H. FLOR²

*Pathologist, Division of Cereal Crops and Diseases, Bureau of Plant Industry,
United States Department of Agriculture*

INTRODUCTION

The results obtained from investigations of physiologic specialization in flax rust (*Melampsora lini* (Pers.) Lév.) during the years 1935 to 1938, inclusive, have rendered inadequate the key for the identification of races presented by the writer in an earlier paper (1)³ and have vitiated some of the conclusions concerning the prospects for developing rust-immune varieties of flax through hybridization. The varieties of common flax (*Linum usitatissimum* L.) formerly reported as immune from all races of flax rust have been found to be susceptible to one or more of the races collected since 1935. Consequently, the number of flax varieties giving a differential reaction to the physiologic races of flax rust (*M. lini*) has been greatly enlarged. The results of investigations made since 1935 are reported in this paper.

MATERIAL AND METHODS

Methods of obtaining and propagating collections of flax rust, of inoculating and incubating flax plants, and of classifying host reactions and types of infection were described by the writer in 1935 (1). All results reported were obtained on flax plants approximately 30 days old, grown in the greenhouse at Fargo, N. Dak., during the winter months November to March, inclusive. The greenhouse was kept at a temperature of about 14° C. at night and 18° to 20° during the day. A light day of 16 hours was maintained during the period of pustule formation by supplementing daylight with artificial illumination from 200-watt Mazda bulbs. Final readings of the classes of host reaction and types of rust infection were made 10 to 15 days after inoculation, depending upon the effect of temperature and light on the rapidity of pustule development.

EXPERIMENTAL RESULTS

NEW DIFFERENTIAL VARIETIES OF FLAX

In order to differentiate the races of *Melampsora lini* collected since 1935, it has been necessary to add three varieties, Argentine (C. I. 462),⁴ Bombay (C. I. 42), and Ottawa 770 B (C. I. 355), to the former list of differential varieties. These three varieties have been either immune from or susceptible to every race of rust thus far isolated, under all conditions encountered in the greenhouse.

¹ Received for publication February 7, 1940. Cooperative investigations between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the North Dakota Agricultural Experiment Station.

² The writer is indebted to A. C. Dillman, associate agronomist, Division of Cereal Crops and Diseases, for supplying seed of 150 or more varieties, for the preliminary grouping of varieties as shown in the tables, and for a critical reading of the manuscript. The writer is also indebted to A. C. Army, associate agronomist, Minnesota Agricultural Experiment Station, and to José Vallega, of the Instituto Fitotécnico, Llavallol, Argentina, for supplying seed of a number of varieties.

³ Italic numbers in parentheses refer to Literature Cited, p. 591.

⁴ C. I. refers to accession number of the Division of Cereal Crops and Diseases.

The original strain of Williston Brown (C. I. 803) was lost. This strain was susceptible to wilt (*Fusarium lini* Bolley) and produced little seed even under favorable climatic conditions, so that no reserve of seed was accumulated. However, several single-plant selections from this strain were grown in the greenhouse during the winter of 1935-36 and from these a strain was secured that has considerable wilt resistance in addition to a more resistant reaction to the races of rust that were differentiated by the original strain of Williston Brown. This new strain (C. I. 803-1) was substituted for the former one. It has the necrotic (type 2) reaction to races to which it is resistant, and is not completely susceptible to many of the races collected in North America. The (type 3) uredia developed normally until they began to produce spores. After 2 or 3 days, development stopped, the pustules ceased to sporulate, and the leaves dried up. To other races it was highly susceptible; the uredia produced spores profusely for a period of 10 days to 2 weeks.

VARIABILITY IN REACTION OF DIFFERENTIAL VARIETIES OF FLAX

It has been customary in classifying rust reaction of crop plants growing under field conditions to take into consideration both the type and the number of pustules. Myers (6) and Vallega (9) followed this method in their classifications of the rust reactions of flax varieties. However, Hart (2) has shown that environmental conditions such as the temperature during the period the plants are in the moist chamber, the temperature during the remainder of the incubation period, and any condition that affects the vigor of the host plant, such as light intensity, temperature, moisture, and mineral nutrition, may alter not only the type but also the number of pustules. These conclusions of Hart have been verified repeatedly in studies made by the writer. In addition, it was observed that apparently identical changes in environmental conditions produced variable responses in different varieties and that the amount and viability of the inoculum affected the reaction of some varieties. The impracticability of accurately controlling the amount of inoculum, and the difficulties in spreading the spores evenly over all the inoculated areas and of rigidly controlling all phases of the environment to which the plant is subjected following inoculation render an attempt to classify degrees of resistance and susceptibility ineffectual. Attempts to differentiate too finely between degrees of resistance and susceptibility may lead to confusion and to a misunderstanding of results obtained at different localities or under variable conditions. A record of observations made on the reactions of the differential varieties when grown under a range of seasonal conditions in the greenhouse at Fargo may assist in the interpretation of results obtained in other localities.

The data presented in this paper were obtained during the winter months under the conditions previously described. However, the reaction range of the differential varieties to races of *Melampsora lini* collected locally has been studied throughout the year. On the basis of these studies with the 24 races of *M. lini* thus far differentiated, the differential varieties have been divided into 4 groups according to the stability of their general reaction under varying conditions and the range of their reaction to given races. These groups are as follows: (1) Stable reaction, always either immune or susceptible; (2) slightly variable reaction, immune, resistant, or susceptible; (3) slightly vari-

able reaction, a wide and almost continuous reaction range with many intermediates; and (4) variable and often intermediate reaction, a wide reaction range with certain races.

The differential varieties classed as having stable reaction have been either immune from or susceptible to every race of rust thus far isolated under all conditions and consequently have made ideal differentials. These varieties are J. W. S.⁵ (C. I. 708-1) and three varieties, namely, Argentine (C. I. 462), Bombay (C. I. 42), and Ottawa 770 B (C. I. 355), that have been added to the list of varietal testers in order to differentiate the new physiologic races of rust.

The three varieties placed in the group having a slightly variable reaction have been immune, resistant, or susceptible to each of the 24 races of flax rust and have been satisfactory as differentials under all seasonal conditions. These varieties, Abyssinian (C. I. 701), Akmolinsk (C. I. 515-1), and Williston Golden (C. I. 25-1), have the chlorotic type of resistance (type 1) in which the uredia are minute to small and scattered in chlorotic areas of the leaves with but little necrosis of adjacent tissue. The distinction between susceptible and resistant-to-immune reaction in Abyssinian and Akmolinsk has been so wide under all conditions that there has been no difficulty in classifying their reaction. Under very favorable growing conditions for flax, the resistant-minus reaction (type 1 to 1+) of Williston Golden approached a susceptible-minus reaction (type 1+ to 3) but did not approximate it closely enough to be confusing.

Buda (C. I. 270-1), the only differential variety placed in the third group, had the most diverse reactions of all varieties tested. Its reaction range extended from immunity, through most of the intermediate stages, to a high degree of susceptibility. However, its range of reaction to any single race of rust was relatively narrow. Under adverse conditions for growth of flax the infection type on Buda sometimes approached that next lower in the scale of susceptibility. When conditions were such that the plants were growing thriftily, no difficulty due to seasonal conditions was encountered in identifying races differentiated by Buda.

The differential varieties in the fourth group had, to many races of rust, an intermediate reaction that was sensitive to changes in environmental conditions, so that considerable care was necessary in differentiating between degrees of resistance or susceptibility. To the races that they differentiated, these varieties had a relatively stable reaction. Two of these varieties, Kenya (C. I. 709-1) and Williston Brown (C. I. 803-1), had the necrotic type of resistance (type 2), in which the inoculated areas of the leaves became necrotic before the uredia were fully developed and the incompletely developed pustules were usually aggregated near the margins of necrotic areas. Isolated pustules were usually well developed but became prematurely surrounded by a necrotic zone. The reaction of "pale blue crimped"⁶ (C. I. 647) to races to which it had an intermediate infection type was peculiar in that this variety became more resistant when growing vigorously under favorable conditions and more susceptible when weakened or retarded by unfavorable growing conditions.

The reaction of Argentine (C. I. 705) to races 1 to 14, inclusive, has been tabulated (1); but, since this variety had the variable reaction

⁵ J. W. S. are the initials of J. W. Stewart, the originator of the variety.

⁶ The word "crimped" is here used to describe the petal margins, which are incurved and somewhat wavy.

of group 4 and since it has not been necessary to use it in the key for the identification of physiologic races, it has been dropped from the list of differential varieties.

NEW PHYSIOLOGIC RACES OF FLAX RUST

Ten physiologic races of flax rust, in addition to the 14 previously described by the writer (1), have been differentiated by the type of infection produced on 11 varieties of cultivated flax.⁷ All varieties that have been tested, including many that formerly were considered immune from flax rust (1, 3, 4, 6), have been found susceptible to 1 or more of the races isolated since 1935. A revised key to the races of *Melampsora lini* follows.

KEY

Buda resistant:		Buda susceptible:	
Williston Golden resistant:		Williston Golden resistant:	
Akmolinsk resistant:	Race	Akmolinsk resistant:	
Williston Brown resistant	10	J. W. S. resistant:	Race
Williston Brown susceptible	1	Kenya resistant	4
Akmolinsk susceptible:		Kenya semiresistant	12
J. W. S. resistant	5	J. W. S. susceptible	13
J. W. S. susceptible	7	Akmolinsk susceptible:	
Williston Golden susceptible:		J. W. S. resistant	8
Akmolinsk resistant:		J. W. S. susceptible	16
"Pale blue crimped" resistant	11	Williston Golden susceptible:	
"Pale blue crimped" susceptible	6	Akmolinsk resistant:	
Akmolinsk susceptible	20	J. W. S. resistant:	
Buda semiresistant:		Bombay resistant	2
Williston Golden resistant:		Bombay susceptible	24
Akmolinsk resistant:		J. W. S. susceptible	9
J. W. S. resistant	17	Akmolinsk susceptible:	
J. W. S. susceptible	15	J. W. S. resistant:	
Akmolinsk susceptible:		Ottawa 770 B resistant	19
Abyssinian resistant	3	Ottawa 770 B susceptible	22
Abyssinian susceptible	18	J. W. S. susceptible	21
Williston Golden susceptible:			
Akmolinsk resistant	14		
Akmolinsk susceptible	23		

The characteristic reaction of seedling plants of 11 differential flax varieties inoculated with 24 physiologic races of *Melampsora lini* and grown in the greenhouse during the winter months at Fargo, N. Dak., is given in table 1.

It will be noted in table 1 that several of the races of flax rust isolated since 1935 have a wider varietal range than any of the 14 races previously described (1). The races of rust having greater virulence, as measured in terms of the number of differential varieties on which they produced a susceptible reaction, were obtained from Minnesota, North Dakota, Oregon, and South America.

Three of the six newly differentiated races of flax rust, collected in Minnesota or North Dakota, were more virulent than any of the races previously collected in this area. Race 16 was the first one isolated to which Buda, Akmolinsk, and J. W. S. were all susceptible and the first race collected in this area to which Abyssinian was not resistant.

⁷ Since the preparation of this manuscript, two reports of work done by Straib in Germany have been published (7, 8). Straib differentiates eight physiologic races apparently different from those previously described by the writer. While several of his new races resemble somewhat certain races described in the present paper, the exact interrelations of these cannot be determined at present since he varied the technique employed by the writer and used additional host testers.

TABLE 1.—Reaction of 11 differential varieties of *Linum usitatissimum* to 24 physiologic races of *Melampsora lini*

Variety	C. I. No.	Reaction ¹ to physiologic race No.—																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Buda.....	270-1	R+	S-	SR	S	R+	I	S	S	S-	R+	S-	S-	R+	SR	SR	R+	SR	SR	S	S	S	S	S	S-
Williston Golden.....	28-1	R	S	R+	R+	S	R+	R+	R+	R+	S	R	R-	S	SR	SR	R+	R	R	S	S	S	S	S	S
Williston Brown.....	803-1	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-
Akmoilansk.....	515-1	R+	R+	S	S	R	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
J. W. S.....	708-1	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
"Pale blue crimped" ¹	647	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-
Kenya.....	709-1	R+	R+	S	S	R	R	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Abyssinian.....	701	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Argentina.....	462	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Ottawa 770 B.....	355	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Bombay.....	42	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I

¹ Plus and minus signs indicate somewhat greater or less resistance or susceptibility than the letter designating the host reaction. The letters signify the following: I, Immune; R, resistant; SR, semiresistant; and S, susceptible.

Race 23 was the only one collected in the midwest seed-flax-producing area to which both Williston Golden and Akmolinsk were susceptible. Bombay, which had been immune from every rust collection previously tested, was susceptible to race 24, collected in North Dakota in 1938. Races 15, 17, and 18 had only minor differences in reaction from those previously described. Both Buda and Williston Golden were more resistant to race 15 than to race 9. The resistance of Akmolinsk differentiated race 17 from race 3. The moderate susceptibility of Abyssinian to race 18 differentiated this race from race 3.

The single uredial collection obtained from Oregon, designated race 21, produced a susceptible or semiresistant reaction on all the differential varieties previously used (1). The three added differentials, Argentine, Bombay, and Ottawa 770 B, were immune from race 21. This was the only North American race, with the exception of race 8, collected in Oregon in 1934, to which Abyssinian was highly susceptible.

Physiologic races 19, 20, and 22, obtained only from South America, possessed infection potentialities distinct from all North American races. Every variety used in differentiating physiologic races of flax rust was either highly susceptible to or immune from these South American races. The Argentine flaxes, formerly considered immune from rust (1, 2, 3, 4, 6), were highly susceptible to races 19, 20, and 22. Bombay, J. W. S., and Ottawa 770 B were immune from race 19; Bombay, Buda, J. W. S., and Ottawa 770 B were immune from race 20; and Bombay and J. W. S. were immune from race 22. The fact that race 22 was found able to attack Ottawa 770 B, which is immune from all other races, is of special importance, as previously this variety had been used as a rust-immune parent in breeding immune varieties of flax in the United States (4). Bombay and J. W. S. were found to be immune from all three races of rust from South America. However, Bombay was susceptible to race 24, from North Dakota, and J. W. S. was susceptible to several other North American races.

Buda was previously reported (1) resistant to race 7, but in subsequent tests has been consistently immune, and it is so classified in table 1.

GEOGRAPHIC DISTRIBUTION OF RACES OF FLAX RUST

Although no systematic survey has been made for the collection and identification of physiologic races of *Melampsora lini*, determinations have been made of collections from various sources. During the 4-year period from 1935 to 1938, 81 race determinations were made in North American urediospore collections. In addition, race determinations were made on two collections of viable telia obtained from South America. Germinating teliospores were used to inoculate flax plants and aecia were developed. A susceptible variety, Bison (C. I. 389), was inoculated with aeciospores from a single aecium, and race determinations were then made by using the urediospores thus produced to inoculate the differential varieties. From one of these telial collections two physiologic races were identified, and from the other collection four physiologic races were identified.

Physiologic races 1 to 18, inclusive, and 21, 23, and 24 were obtained from different localities in North America, and races 19, 20, and 22 were obtained from South America. The distribution of these races and the number of times each race was collected in each location are shown in table 2.

TABLE 2.—*Geographic distribution of physiologic races of Melampyris lini and number of times each race was identified in collections, 1935-38*

Year and source of collection	Isolates of physiologic race No.—																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1935:	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
Canada ¹	1																							
Minnesota.....	4	3	2	1					1		2		1	1	1	3								
North Dakota.....																10								
Uruguay ²																			1					
1936:																	1							
Minnesota.....	2		2	2																				
North Dakota.....			1																		1			
Oregon ³																								
1937:																								
Argentina ⁴			1																					
Minnesota.....	4	3			4	6						1		5			1		1					
North Dakota.....	2	1			1	1								3		1							1	
1938:																								
North Dakota.....	1	1																						1
Texas ⁵																								
Total.....	14	1	13	6	5	7	0	0	1	0	0	3	0	10	1	1	16	1	2	2	1	1	1	1

¹ Collected by W. G. McGregor at Ottawa, Ontario, Canada.
² Collected by J. G. Fischer and Albert Boerger, La Estanzuela, Colonia, Uruguay.
³ Collected by B. B. Robinson at Astoria, Ore.
⁴ Collected by José Vallega, Llavallol, Argentina.
⁵ Collected by E. S. McFadden, at Victoria, Tex.

There appeared to have been little change since the earlier report (1) in the races of rust that predominated in the midwest seed-flax-producing area. The ones with a more limited varietal range continued to be predominant, although there were races present that had a wider varietal host range. Since the principal commercial seed-flax variety, Bison, is susceptible to all known races of flax rust, there probably was no natural selective survival going on among the more widely virulent strains, such as might take place if a variety were grown that was resistant to the present prevailing races but susceptible to those races having a wider varietal range.

Races 19 and 20 were segregated from a telial collection obtained from Uruguay. These 2 races also predominated in the aecial isolates made from the telial collection received from Argentina, and races 3 and 22 also were obtained from these latter isolates. Races 19, 20, and 22 were obtained only from South America and therefore special care was taken to prevent their escape from the greenhouse. Tests were conducted only during the winter months and all plant parts, pots, and soil were steamed before being discarded.

In 1938, a uredial collection sent from a Texas flax field sown with Bison seed obtained from North Dakota was identified as race 14. This race was prevalent in Minnesota and North Dakota flax fields the preceding year and the Texas infection probably originated from telia sown with the seed.

Race 24 was isolated from a row of heavily rusted Bombay sown in the field at Fargo, N. Dak., in 1938. This seed was obtained from José Vallega, who reported this variety immune in Argentina (9).

REACTION OF VARIETIES OF FLAX

One of the objects of a study of physiologic specialization in parasitic organisms is to facilitate the production of immune or resistant varieties of crop plants. A knowledge of the regional and world-wide reaction of the parental material to the disease-producing organism is essential, especially when the highly specialized rusts are involved. In the data presented in an earlier paper (1), based on a study of North American collections of *Melampsora lini*, so few of the flax varieties showed differential response to the physiologic races then isolated that it was considered more desirable, in recording the reaction of varieties, to list them according to type of flax rather than according to their response to the different races of flax rust. The varietal specificity of several of the more recently isolated races of flax rust has made it desirable to group the flax varieties on the basis of their differential reaction to the races of rust thus far isolated. On this basis the 201 varieties and strains of flax that have been tested with the 16 principal physiologic races, Nos. 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 19, 20, 21, 22, 23, and 24, have been grouped as follows: (1) Varieties and strains susceptible to all these races; (2) those having the specific immunity of (a) Argentine, (b) Ottawa 770 B, (c) J. W. S., and (d) Bombay; (3) those having varying degrees of resistance and susceptibility; and (4) those too heterogeneous to classify as to predominant type of reaction. The several races that were not included have pathogenic properties differing but slightly from one or more of those used in these tests and the additional information would not have warranted the increased cost in time and effort their use would have entailed. Cases where the variety was not pure for rust reaction and instances

where a variety consistently exhibited an intermediate type of reaction have been noted.

The varieties and strains of flax predominantly susceptible to all 16 physiologic races of *Melampsora lini* that were used are listed in the following tabulation. Of the 201 varieties and strains of flax tested, 91 were in this group.

Varieties of flax susceptible to physiologic races 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 19, 20, 21, 22, 23, and 24 of Melampsora lini and immune from none

Group and variety	C. I. No.	Group and variety	C. I. No.
Dehiscent flax (<i>Linum usitatissimum crepitans</i>):		Seed flax—Continued.	
From Siberia	295	Petals broad, flat—Continued.	
From Germany	469	American and European—Con.	
From Ukraine	506	Pink-flowered:	
Do	507	Deep pink	648
Seed flax (<i>Linum usitatissimum</i>):		Long No. 4	400
Petals broad, flat:		Long No. 66	337
Abyssinian:		Do	719
Abyssinian Yellow-seed ..	36	Long No. 83	354
Abyssinian	300	Pale pink	² 173-1
Do	¹ 302	Do	² 173-3
Abyssinian from Egypt ..	¹ 380	Pale pink (M25-228) ..	479
Abyssinian from Kenya,		Tall pink	451-3
East Africa	707	Tammes pink	334
American and European:		Tammes pink, type 8 ..	772
Blue-flowered:		Tammes deep pink ..	336
Bison	389	Tammes deep pink,	
Bolley No. 32-1823 ..	² 754	type 9	¹ 773
Buda	326	Argentine:	
Linota	244	Capa	³ 720
Minnesota 25-410	421	De Sanare	³ 1002
Minnesota 25-202	447	Klein 10 e	³ 887
Minnesota 25-221	423	Rosario	³ 316
Minnesota 25-245	446	Indian:	
Minnesota 25-107	438	Howard and Khan (5):	
Minnesota 25-241	458	var. <i>luteum</i> , type 1	
North Dakota Resist-		var. <i>cyaneum</i> , type 8 ..	
ant 5	411	var. <i>purpureum</i> , type	
North Dakota Resist-		11	
ant 52	275	var. <i>album</i> , type 15	(⁴)
North Dakota Resist-		var. <i>agreste</i> , type 22 ..	
ant 114	489	var. <i>meridionale</i> , type	
North Dakota Resist-		25	
ant 714	399	var. <i>pratense</i> , type 28 ..	
North Dakota Resist-		Russian:	
ant 726	412	Billings	³ 184
North Dakota 40016 ..	428	Crimean (No. 2237) ⁵ ..	³ 563
Pale blue	387-1	Fergana (No. 401) ⁵ ..	512
Redwing	320	Novelty	³ 140
Slope	274	Samarkand (No. 2238) ⁵ ..	³ 514
Winona	481	Hybrid:	
Argentine × Saginaw ..	660	Petals narrow, margins	
White-flowered:		incurved or crimped:	
Blanc	323-3	Crimped white (Minn.	
Diadem	³ 321	25-125)	392
Ottawa white-flowered ..	24	Crimped white (Minn.	
Tammes white	329	29-55)	⁶ 685
Tammes white, type 10 ..	774	Ottawa 829-C	391
Tammes yellow seed	331	Pale blue	³ 646
Tammes yellow seed,		Tammes crimped white ..	330
type 13	777	Tammes crimped white,	
		type 11	775

See footnotes at end of table.

Varieties of flax susceptible to physiologic races 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 19, 20, 21, 22, 23, and 24 of *Melampsora lini* and immune from none—Continued

Group and variety	C. I. No.	Group and variety	C. I. No.
Seed flax—Continued.		Fiber flax—Continued.	
Petals broad, flat—Con.		Blue-flowered—Con.	
Hybrid—Continued.		Liral Crown.....	882
Petals narrow, etc.—Con.		Peerless.....	695
Tammes type 12 (seeds		Saginaw.....	449
brown).....	776	Stormont Cirrus.....	881
Yellow seed B.....	325	Stormont Gossamer.....	³ 883
Fiber flax (<i>Linum usitatissimum</i>):		White-flowered:	
Blue-flowered:		Blenda.....	
Althausen.....	628	Concurrent.....	801
Do.....	¹ 630	Friesland white.....	56-1
Dalgonetz.....	498	Minnesota 25-64.....	420
F. I. ⁷ No. 3.....	³ 694	Pinnacle.....	693
Hercules.....		Saginaw white.....	448
J. W. S.....	¹ 388		

¹ Some plants resistant to or immune from each race.

² Susceptible (S-) to most North American races. S- denotes a susceptible-minus host reaction in which the uredia are large but less abundant than in a susceptible reaction and in which there is considerable distortion and chlorosis or necrosis of the infected leaf tissues.

³ Some plants resistant to or immune from North American races.

⁴ Susceptible (S-) to race 10.

⁵ Obtained from Dr. N. I. Vavilov, Union of Soviet Socialist Republics, in March 1930.

⁶ Some plants immune from all races except race 22.

⁷ F. I. = Fiber investigations.

While there was no absolute correlation between flax type and rust reaction, there appeared to be definite relationships. The four strains of dehiscent flax (*Linum usitatissimum* var. *crepitans* Bönningh.) were uniformly susceptible. Most American and European seed flax varieties, as well as most fiber flax varieties, were susceptible to all races of rust. However, there were a few varieties in these groups that possessed resistance to or immunity from certain races. Several varieties of Abyssinian and of Indian type were highly susceptible, as also were a number of varieties having narrow incurved or crimped petals. Most of the Argentine and Russian flaxes listed as predominantly susceptible were not pure for rust reaction and contained varying percentages of plants immune from North American races but susceptible to races 19, 20, and 22 from South America.

It is possible that some of the varieties listed as susceptible to all races may give a differential reaction when tested with additional races of rust. No European rust collection has been tested, but the report by Henry (3) that flax varieties resistant or immune in The Netherlands were susceptible in Minnesota would indicate the existence of varieties susceptible to North American races but resistant to or immune from some European races. The variety Rosario (C. I. 316) and two selections of "pale pink" (C. I. 173-1 and 173-3) that formerly were reported (1) as resistant to North American races have been found to be somewhat susceptible and have been included among the susceptible varieties listed in the tabulation on pages 583-584.

It has been pointed out that four of the differential varieties, Argentine, Bombay, J. W. S., and Ottawa 770 B, have been either immune from or susceptible to each of the 24 races of flax rust. The reaction of these varieties suggests that each possesses a factor or factors for immunity from certain races of rust not common to the other three varieties. The studies that have been made on the inheritance of immunity from rust in flax bear this out. Henry (4) found that immunity from races of North American rust was dominant

and conditioned by a single factor in the varieties Bombay and Ottawa 770 B and by two factors in a selection of Argentine type. Myers (6) verified Henry's results in regard to Ottawa 770 B. He also found that the immunity of an Argentine flax (C. I. 712) could be explained by assuming the existence of two dominant factors governing rust reaction, one factor determining immunity and the other near-immunity from a North American rust collection. Unpublished data obtained by the writer have shown that immunity in J. W. S. is conditioned by a single dominant factor. Flax varieties having rust reactions similar to that of each of the differential varieties Argentine, Ottawa 770 B, J. W. S., and Bombay have been grouped in the following tabulations to facilitate inventories of potential parental material for breeding rust-immune flax.

Flaxes of Argentine type were immune from all North American rust collections but highly susceptible to races 19, 20, and 22 from South America. Varieties having either or both of the factors for immunity or near-immunity from North American rusts as found by Henry (4) and Myers (6) are in this group. Most of these varieties are definitely of the Argentine type or hybrids in which an Argentine type of flax was a parent. However, three pink-flowered American seed flaxes, one Indian, three Mediterranean, and two Russian type flaxes had the rust reaction characteristic of Argentine type varieties. Varieties and strains having the reaction of the Argentine type flaxes are listed in the following tabulation.

Varieties of seed flax (Linum usitatissimum) susceptible to physiologic races 19, 20, and 22 of Melampsora lini, and immune from races 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 21, 23, and 24

Group and variety	C. I. No.	Group and variety	C. I. No.
American and European:		Indian:	
Pink-flowered:		Howard and Khan (5):	
Bolley Golden.....	1 644	var. <i>pulchrum</i> , type 34.....	—
Bolley No. 32-1822.....	750	Mediterranean:	
Smoky Golden.....	751	Beladi.....	6 377
Argentine:		Giza.....	1 378
Argentine (N. Dak. 1742) ..	1 342	Morocco.....	2 376-2
Argentine (Minn. 25-343) ..	2 417	Russian:	
Argentine (Minn. 25-341) ..	462	Damont.....	3
Argentine (Minn. 25-362) ..	472	Newland.....	2 188
Argentine (Minn. 25-330) ..	1 690	Hybrid:	
Argentine (Minn. 25-361-1)	1 691	Argentine × Saginaw.....	651
Argentine (Selection C. I.		Do.....	652
379-3).....	2 692	Do.....	653
Argentine (Minn. 25-323) ..	2 705	Do.....	7 654
Biglow.....	2 414	Do.....	656
Capa 10.....	3 721	Do.....	657
Capa 11.....	722	Do.....	7 658
Kenya.....	4 706	Do.....	7 661
Do.....	2 709	Do.....	664
Light Mauve.....	5 379-1	Do.....	667
Lineta Z 195.....	6 1003	Bolley 37-5310.....	877
Lino Grande.....	1 381-2	Bolley 37-5242.....	878
Long No. 5.....	2 466	Natural hybrid, Rosario.....	820
Malabrigo.....	1 346	Selection Bison × (160 ×	
Do.....	696	179).....	818
Rio.....	280	Selection (19 × 112) × 19..	819

See footnotes at end of table.

Varieties of seed flax (*Linum usitatissimum*) susceptible to physiologic races 19, 20, and 22 of *Melampsora lini*, and immune from races 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 21, 23, and 24—Continued

Group and variety	C. I. No.	Group and variety	C. I. No.
Hybrid—Continued.		Hybrid—Continued.	
Selection of C. I. 385 (19 × 112)-----	823	Selection of C. I. 385 (19 × 112)-----	825
Selection of C. I. 496 (160 × 179)-----	824	Walsh-----	¹ 645

¹ Some plants resistant to North American races.

² Some plants resistant or susceptible to North American races.

³ Resistant to races 16, 21, and 23.

⁴ Some plants resistant to all races except 22.

⁵ Resistant to North American races.

⁶ Some plants immune from races 19 and 20.

⁷ Some plants susceptible to North American races.

The high proportion of varieties having the Argentine type of rust reaction, but not pure for immunity from North American races of flax rust, may be due (1) to a relatively high percentage of natural crossing in these varieties or (2) to an immune and to a near-immune or resistant factor for rust reaction, as pointed out by Myers (6).

The varieties with the reaction of Ottawa 770 B, i. e., immune from all races except race 22 from South America, are listed in the following tabulation.

Varieties of seed flax (*Linum usitatissimum*) susceptible to physiologic race 22 of *Melampsora lini*, and immune from races 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 17, 18, 19, 20, 21, 23, and 24

Group and variety	C. I. No.	Group and variety	C. I. No.
Petals broad, flat:		Petals narrow, etc.—Continued.	
Argentine:		Minnesota hybrids—Continued.	
Bolley 37-5012-----	¹ 874	Saginaw × Ottawa 770 B—Continued.	
Klein 11-o-----	1004	Do-----	682
Lineta Z 176-----	885	Do-----	684
Pergamino selection-----	884	Do-----	685-1
Tammes pale blue-----	¹ 333	Do-----	686
Petals narrow, margins incurved or crimped:		Do-----	687
Ottawa 770 B-----	355	Do-----	² 681
Minnesota hybrids:		Winona × Ottawa 770 B---	672
Saginaw × Ottawa 770 B----	675	Do-----	673
Do-----	676	Do-----	674
Do-----	677	Do-----	716
Do-----	679		

¹ Some plants susceptible to all races.

² Some plants susceptible to races 19 and 20.

Most of these varieties were hybrids in which Ottawa 770 B was a parent. The origin of Tammes pale blue and of the four varieties from Argentina having rust reaction similar to that of Ottawa 770 B was not available.

The four varieties that were immune from the same physiologic races as the differential selection of J. W. S. are listed in the following tabulation.

Varieties of flax (*Linum usitatissimum*) susceptible to physiologic races 7, 9, 16, and 21 of *Melampsora lini*, and immune from races 1, 2, 3, 4, 5, 8, 10, 19, 20, 22, 23, and 24

Group and variety	C. I. No.	Group and variety	C. I. No.
Seed flax:		Fiber flax:	
Petals broad, flat:		Blue-flowered:	
Italia Roma.....	¹ 1005	J. W. S.....	708-1
Tammes light blue.....	332		
Tammes light blue, type 2..	766		

¹ Not highly susceptible to races 7, 9, 16, and 21.

Tammes light blue types were identical and pure for rust reaction. Italia Roma (C. I. 1005), in addition to being immune from the races to which the J. W. S. selection and Tammes light blue types were immune, was somewhat resistant to the races to which these varieties were susceptible. The reaction of Italia Roma suggested that it had a modifying factor for resistance in addition to the factor for immunity possessed by the differential strain of J. W. S.

The eight varieties listed in the following tabulation had previously been considered immune from all races of flax rust but were susceptible to race 24 found in field plots at Fargo, N. Dak., in 1938. These are all Indian types or hybrids in which an Indian type flax was a parent. The 12 varieties listed in the following tabulation and in that immediately preceding were the only varieties tested that were not predominantly susceptible to race 22 from South America.

Varieties of seed flax (*Linum usitatissimum*) susceptible to race 24 of *Melampsora lini*, and immune from races 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 19, 20, 21, 22, and 23.

Group and variety	C. I. No.	Group and variety	C. I. No.
Indian:		Hybrid:	
Howard and Khan (5):		Saginaw × Bombay.....	671
var. <i>minor</i> , type 29.....		Vallega 2181-1.....	
var. <i>commune</i> , type 46...			
var. <i>commune</i> , type 48...			
var. <i>commune</i> , type 53...			
Bombay.....	42		
Punjab.....	20		

The varieties that had reactions intermediate between "immune" and "susceptible" to one or more races of *Melampsora lini* are listed in table 3. The seven differential varieties that were neither immune from nor susceptible to each race are included in this table. Two selections of Buda × (19×112) (C. I. 821 and 826) had reactions identical with those of the differential line of Buda. The reaction of Abyssinian (C. I. 511) was similar to that of the differential selection of Akmolinsk (C. I. 515-1). The other varieties listed in table 3 deviated from each of the differential varieties in their reaction to one or more physiologic races of rust. This suggests that these varieties possess factors or combinations of factors modifying rust reaction not possessed by any of the 11 differential varieties listed in table 1. It is probable that several of these varieties may be of value in differentiating new physiologic races of flax rust.

The reaction to North American races of rust of several varieties listed in table 3 was found to be affected by small variations in environment and thus was extremely variable. The reactions of "pale pink" (C. I. 649), Indian type 55, "pale blue" (C. I. 176), and "pale blue crimped" (C. I. 647) were especially subject to modification by a variable environment.

TABLE 3.—Reaction of varieties of seed flax (*Linum usitatissimum*) having intermediate differential reactions to physiologic races of *Melampora lini*

Group and variety	C. I. No.	Predominant reaction ¹ of 30-day-old plants to physiologic race No.—																
		1	2	3	4	5	7	8	9	10	16	19	20	21	22	23	24	
Petals broad, flat:																		
Abyssinian:																		
From Fergana.....	511	R	R	S	R	S	R	S	R	R	S	S	S	S	S	S	S	R
Abyssinian.....	701	I	I	R	I	R	I	S	I	I	S	S	S	S	S	S	S	S
American and European:																		
Blue-flowered:																		
Buda.....	270-1	R	S-	SR	S	R+	I	S-	R+	R+	S	S	I	S	S	S	SR	S-
Williston Brown.....	803-1	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-
Pink-flowered:																		
Lethbridge Golden.....	23	S	S	S	R	S	R	S	R	R	S	S	S	S	S	S	S	S
Pale pink.....	649	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Williston Golden.....	25-1	R	S	R+	R+	R-	R+											
Argentine:																		
Argentine (Minn. 25-323).....	705-1	SR	SR	SR	SR	SR	S-	SR	SR	SR	SR	S	S	S	S	S	SR	SR
Bolley (37-5090).....	879	R	R	R	R	R	S-	R	R	R	R	S	S	S	S	S	R	R
Kenya.....	709-1	R+	R+	SR	R	R+	SR	SR	R	R+	R	R						
Indian:																		
Howard and Khan (5):																		
var. <i>commune</i> , type 55.....		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
var. <i>compestris</i> , type 68.....		I	I	R	R	R	S-	I	R	I	R	R	S-	S-	S-	S-	S-	S-
var. <i>saituum</i> , type 121.....		R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Russian:																		
Akmolinsk.....	515-1	R+	R+	S	R	S	S	S	R+	R+	S	S	S	S	S	S	S	R+
Pale blue.....	176	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Hybrid:																		
Selection Buda X (19 X 112).....	821	R	S-	SR	S	R+	I	S-	R+	R+	S	S	I	S	S	S	SR	S-
Do.....	826	R	S-	SR	S	R+	I	S-	R+	R+	S	S	I	S	S	S	SR	S-
Selection (19 X 112) X Buda.....	822	R	S-	SR	S	R+	I	S-	R+	R+	S	S	I	S	S	S	SR	S-
Selection Buda X (19 X 112).....	827	R	S-	SR	S	R+	I	S-	R+	R+	S	S	I	S	S	S	SR	S-
Petals narrow, margins incurved or crimped:																		
Pale blue crimped ²	647	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-	S-

¹ I = immune, R = resistant, SR = semiresistant, and S = susceptible. Plus and minus signs indicate somewhat more or less resistance or susceptibility than the letter designating the host reaction.

² Immune from physiologic race 11.

The varieties in which the rust reaction was so mixed that it was difficult to determine the predominant reaction with each race are listed in the following tabulation. Six of the 11 varieties listed in this table were pure for susceptibility to South American races 19, 20, and 22.

Varieties of seed flax (Linum usitatissimum) too heterogeneous to classify as to predominant type of reaction to physiologic races 1, 2, 3, 4, 5, 7, 8, 9, 10, 16, 19, 20, 21, 22, 23, and 24 of Melampsora lini in greenhouse tests

Group and variety	C. I. No.	Group and variety	C. I. No.
Mediterranean:		Hybrid:	
Crete.....	¹ 31-1	Bolley (37-5066).....	¹ 876
Cyprus.....	689	Long No. 125.....	¹ 356
Russian:		Reserve × Morye (19×112).....	486
Akmolinsk.....	² 520	Tammes, type 1 (common blue).....	765
North Caucasian.....	³ 620	Tammes, type 3.....	767
Winter:			
Roman Winter.....	¹ 470		

¹ Susceptible to races 19, 20, and 22.

² Susceptible to races 19, 20, 21, and 22.

³ Some plants immune from each race.

DISCUSSION

The production of rust-immune varieties of flax has been rendered more difficult by the discovery of new physiologic races of *Melampsora lini* to which all the varieties that had previously been considered immune were susceptible. Henry (3) noted that certain strains of Argentine flax, strains of Williston Golden, several varieties obtained from India, and Ottawa 770 B were immune in tests made in Minnesota. In his hybridization studies, he used selections of Argentine, Ottawa 770 B, and an Indian variety, Bombay, as supposedly rust-immune parents. In tests reported upon in this paper, all strains of Williston Golden were found to be highly susceptible to several races of flax rust prevalent in North America, while Bombay and several other Indian flaxes that were previously considered to be immune were susceptible to race 24 collected at Fargo, N. Dak. Ottawa 770 B and certain Argentine strains were immune from all races collected in North America but were susceptible to race 22 from South America. All of Henry's supposedly rust-immune hybrid strains that have been tested by the writer have been found to be susceptible to certain races and to have the reaction of the supposedly rust-immune parent. Myers (6) used Newland (C. I. 188) and a strain of Bolley Golden (C. I. 644), in addition to Ottawa 770 B and an Argentine selection, as immune parents in his studies on inheritance of rust reaction in flax. In the present studies all of these varieties were found to be susceptible to race 22 and also, with the exception of Ottawa 770 B, to races 19 and 20 from South America. Not one of the 201 varieties tested was immune from or resistant to all of the 24 races of flax rust thus far differentiated. These varieties had been selected for testing because of their diverse morphologic type, their agronomic importance, or their reported resistance to or immunity from rust. While all possibilities have not been exhausted there is a basis for doubt as to the existence of a variety of common flax immune from all races of rust.

There is a possibility, however, that a variety immune from all races of flax rust could be developed by hybridization. The varieties that apparently have the same factor for immunity as J. W. S. and

those that apparently have the same factor as Bombay were immune from races to which the Argentine type flaxes and Ottawa 770 B were susceptible. The latter varieties were, in turn, immune from those races of rust to which J. W. S. or Bombay were susceptible. No data exist as to combining in one variety these factors for immunity. Myers (6) found in a cross between two immune varieties, Newland and Ottawa 770 B, that immunity was conditioned by a single dominant factor in each variety and that the factors in the two varieties were not allelic. In the cross between the immune varieties Ottawa 770 B and Argentine selection (C. I. 438), his results suggested that C. I. 438 carried the same factor that conditioned immunity to Ottawa 770 B and also a factor for resistance that was allelic to the factor for immunity carried by Newland. The susceptibility of C. I. 438 to races 19 and 20, and the immunity of Ottawa 770 B from these races would indicate that Myers' suggestion of identical factors for immunity in these two varieties was not correct. The factor for immunity from the North American rusts used by Myers in C. I. 438 was probably allelic to the factor for immunity from North American rusts and races 19 and 20 from South America in Ottawa 770 B. This difference between the immune factors in these two varieties would not be apparent with the rusts used by Myers. If the factors for immunity carried by either Bombay or J. W. S. are not allelic to the factor for immunity carried by either Ottawa 770 B or Newland, it should be possible to develop a variety immune from all the known races of *Melampsora lini*.

There is a relatively wide range of flax varieties and types available for parental material having the resistance of the Argentine differential. Varieties in this group included American pink-flowered seed flaxes and Argentine, Indian, Mediterranean, Russian, and hybrid types. Choice of varieties available for parental material having the factors for immunity of the other three immune groups is relatively limited. Of the 20 varieties and selections having the immune reaction of Ottawa 770 B, 13 were Ottawa 770 B hybrids. Only 4 varieties had the immune reaction of J. W. S. Two of these were apparently identical strains of Tammes light-blue type 2. All 8 varieties that had the immune reaction of Bombay were Indian type flaxes or hybrids in which an Indian type flax was a parent.

Even if it is found possible to develop a strain of flax immune from all known races of *Melampsora lini*, the possibility of the rust hybridizing and developing a new race capable of attacking the immune flax should not be overlooked. In temperate regions, flax rust overwinters in the telial stage and the initiation of infection in the spring is dependent upon a natural hybridization process. It appears desirable to determine the inheritance of the factors governing different degrees of pathogenicity in the rust organism as well as those governing immunity in the host. Until this is done it seems desirable to exercise all possible precautions against the establishment in North America of the races attacking Ottawa 770 B, Newland, and Argentine flaxes. Similar precaution should be taken against the establishment in South America of races attacking Bombay and J. W. S.

SUMMARY

Ten new physiologic races of flax rust (*Melampsora lini*), in addition to the 14 previously reported, have been identified by the reaction of

11 varieties of flax. To differentiate the new races it was necessary to add 3 varieties, previously considered immune from rust, to the list of host testers. These are Argentine (C. I. 462), Bombay (C. I. 42), and Ottawa 770 B (C. I. 355).

All of the 201 varieties and strains of flax tested were susceptible to 1 or more of the 24 physiologic races of *Melampsora lini* that have been identified. These varieties and strains were selected for testing because of their diverse morphologic type, their commercial possibilities, or their reported resistance to or immunity from flax rust. Flaxes of Argentine type and Ottawa 770 B remained immune from all races of rust collected in North America but were susceptible to one or more of the races from South America.

Bombay and J. W. S. were immune from the races of rust obtained from South America but were susceptible to one or more of the North American races.

Pathogenicity tests indicate that each of the differential varieties Argentine, Bombay, J. W. S., and Ottawa 770 B possesses distinct factors governing immunity from specific races of flax rust. Of 201 varieties tested, 48 had the reaction of Argentine, 8 the reaction of Bombay, 4 the reaction of J. W. S., and 20 the reaction of Ottawa 770 B to 16 physiologic races of *Melampsora lini*.

The races of flax rust with a rather limited varietal range continued to predominate in the seed-flax-producing area of the Midwest despite the presence of a number of the races possessing a wider varietal range.

LITERATURE CITED

- (1) FLOR, H. H.
1935. PHYSIOLOGIC SPECIALIZATION OF MELAMPSORA LINI ON LINUM USITATISSIMUM. Jour. Agr. Res. 51: 819-837, illus.
- (2) HART, HELEN.
1926. FACTORS AFFECTING THE DEVELOPMENT OF FLAX RUST, MELAMPSORA LINI (PERS.) LÉV. Phytopathology 16: 185-205, illus.
- (3) HENRY, A. W.
1926. FLAX RUST AND ITS CONTROL. Minn. Agr. Expt. Sta. Tech. Bul. 36, 20 pp., illus.
- (4) ———
1930. INHERITANCE OF IMMUNITY FROM FLAX RUST. Phytopathology 20: 707-721, illus.
- (5) HOWARD, GABRIELLE L. C., and KHAN, ABDUR RAHMAN.
1924. STUDIES IN INDIAN OIL SEEDS NO. 2. LINSEED. India Dept. Agr. Mem., Bot. Ser. 12: 135-183, illus.
- (6) MYERS, W. M.
1937. THE NATURE AND INTERACTION OF GENES CONDITIONING REACTION TO RUST IN FLAX. Jour. Agr. Res. 55: 631-666, illus.
- (7) STRAIB, W.
1939. ZUM EPIDEMISCHEN AUFTRETEN DES LEINROSTES IN OSTPREUSSEN. Nachrichtenbl. f. den Deut. Pflanzenschutzdienst 19: [49]-51.
- (8) ———
1939. UNTERSUCHUNGEN ÜBER DEN WIRTSBEREICH UND DIE AGGRESSIVITÄT PHYSIOLOGISCHER RASSEN VON MELAMPSORA LINI (PERS.) LÉV. Züchter 11: 130-136, 162-168, illus.
- (9) VALLEGA, JOSÉ.
1938. OBSERVACIONES SOBRE LA RESISTENCIA A LA ROYA DE ALGUNOS LINOS ENSAYADOS EN EL INSTITUTO FITOTÉCNICO DE LLAVALLOL. Santa Catalina Inst. Fitotéc. Pub. No. 1, 34 pp. [From Rev. Argentina de Agron., t. 5, No. 1.]

