U. of M.

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Godfrey Richard Hoerner final oral examination for the degree of Master of Science . We recommend that the degree of Master of Science be conferred upon the candidate.

Minneapolis, Minnesota

June 3 191

E C Stakman
Chairman

Fred. K. Butters

M. J. Dorsey

231229

Nov 29 - 1915 Pd. E b

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Godfrey Richard Hoerner for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

E. E. Stockman
Chairman

Fred. K. Butters

M. J. Dorsey

June 7 1918

INFECTION CAPABILITIES OF CROWN RUST OF OATS

A Thesis submitted to the Faculty of the Graduate School of the University of Minnesota by G. R. Hoerner in partial fulfillment of the requirements for the Degree of Master of Science

June 1918

--o--

TABLE OF CONTENTS

---o---

INFECTION CAPABILITIES OF CROWN RUST OF OATS

INTRODUCTION

General: Crown rust of oats is practically coextensive with the culture of the host crop. It has generally been considered the most destructive of any of the American leaf rusts of cereals. European writers as a whole do not consider it of primary importance. On the North American continent, the fact that it is commonly associated with the stem rust makes a fair estimate of the losses occasioned difficult. In the southern and western United States especially, however, there is no doubt that it is often times a limiting factor in oat production.

Historical: The crown rust of oats has long been of scientific interest. The puccinial stage was first described by Corda (1837)[6] as Puccinia coronata.

Anton De Bary (1865)[2] definitely established the heteroecious life history of this species.

Nielsen (1875),[16] by means of careful culture work, proved that the P. coronata of Corda was in reality a group species capable of being separated, on the basis of the aecidial host, into two distinct species. For the form producing its aecidia on Rhamnus Frangula he retained the name P. coronata Cda. The form having its aecidial stage on Rhamnus cathartica, he called P. lolii Niels.

Klebahn (1893),[11] by a series of inoculation experiments, really substantiated Nielsen's division but substituted the name P. coro-

nifera for that of P. lolii Niels. He offers (1904)[12] the following reasons in support of this substitution:

"Magnus has recently attempted to show that the differentiation between P. coronifera and P. coronata has, as a matter of fact, previously been established by Nielsen under the name of P. lolii.

"I can here only repeat that the aggregate attempts of Nielsen have already been cited by me, but that the same in themselves are not sufficient for the differentiation of the two fungi. The name P. lolii cannot be applied in the place of P. coronifera because only one of the forms of this rust can live on Lolium.

"Also within P. coronifera specialized forms have been differentiated by Eriksson and myself as follows:

1. Pucc. coronifera Avenae Erikss.

   Aecidiospores obtained from teleutospores from Avena sativa, as well as uredospores from Avena sativa, infected Avena sativa but not Festuca elatior, Lolium perenne, Holcus mollis, Holcus lanatus, Dactylis glomerata or Arrhenatherum elatius.

2. Pucc. coronifera Lolii Erikss.

   Uredospores from Lolium perenne infected only Lolium perenne, Holcus lanatus and Festuca elatior but slightly, not Avena sativa. Nielsen maintained that the uredospores from Lolium perenne successfully infected Avena sativa upon which teleutospores were also produced.

3. Pucc. coronifera Festucae Erikss.

   Aecidiospores produced from teleutospores on Festuca elatior infected only Festuca elatior, not Avena sativa, Alopecurus pratensis, Holcus mollis, Holcus lanatus or Lolium perenne.

Uredospores from Festuca elatior infected Festuca elatior but not Avena sativa, Alopecurus pratensis, Glyceria aquatica, Holcus mollis or Holcus lanatus.

Lolium perenne which remained in Eriksson's experiment free from rust was comparatively well infected by Klebahn.

The independence of the form Festucae needs perhaps further proof.

4. Pucc. coronifera Holci Kleb.

Aecidiospores obtained from teleutospores on Holcus lanatus infected Holcus mollis and Holcus lanatus, but not Festuca elatior or Lolium perenne. This was also true of the uredospores.

5. Pucc. coronifera Alopecuri Erikss.

Uredospores from Alopecurus pratensis infected Alopecurus pratensis but not Avena sativa.

Aecidiospores from teleutospores on Alopecurus pratensis infected Alopecurus heavily but Avena only weakly.

Aecidiospores from teleutospores on Alopecurus nigricans infected Alopecurus pratensis but not Avena sativa, Festuca elatior or Glyceria aquatica.

6. Pucc. coronifera Glyceriae Erikss.

Aecidiospores from teleutospores from Glyceria aquatica infected Glyceria aquatica but not Avena sativa, Alopecurus pratensis or Festuca elatior.

The uredospores infected Glyceria but not Avena or Festuca."*

* Free translation from the German.

Eriksson (1909)[8], lists the form species of P. coronifera Kleb., as follows:

1. f. sp. Avenae

   On Avena sativa and Avena brevis but not on Alopecurus pratensis, Festuca elatior, Lolium perenne, Triticum repens, Holcus lanatus or Holcus mollis.

2. f. sp. Alopecuri

   On Alopecurus pratensis and Alopecurus arundinaceus, occasionally on Avena sativa but not on Festuca elatior or Glyceria aquatica.

3. f. sp. Festucae

   On Festuca elatior and Festuca gigantea but not on Festuca arundinacea, Avena sativa, Alopecurus pratensis, Lolium perenne, Glyceria aquatica or Holcus mollis.

4. f. sp. Lolii

   On Lolium perenne, sometimes on Festuca elatior but not on Avena sativa, Alopecurus pratensis, Glyceria aquatica, Holcus lanatus, Triticum repens or Festuca arundinacea.

5. f. sp. Glyceriae

   On Glyceria aquatica but not on Avena sativa, Alopecurus pratensis, or Festuca elatior.

6. f. sp. Agropyri

   On Triticum repens, but not on Avena sativa, Alopecurus pratensis, Festuca elatior or Lolium perenne.

7. f. sp. Epigaei

   On Calamagrostis epigeios and sometimes on Avena sativa but not on Alopecurus pratensis, Festuca elatior or Calamagrostis arundinacea.

8. f. sp. Holci

On Holcus lanatus but not on Avena sativa.

Mühlenthaler (1911)[15] gives the following subdivision for P. coronifera Kleb:

1. f. sp. Avenae
2. f. sp. Alopecuri
3. f. sp. Festucae

On Festuca elatior, arundinacea, gigantea, varia, alpina but not on Festuca ovina, heterophylla, amethystina, Halleri, rupicaprina or Bromus erectus.

4. f. sp. Lolii

On Lolium remotum var. aristatum, temulentum, perenne, rigidum, italicum, Festuca elatior but not on Avena sativa, pubescens, elatior, Alopecurus pratensis, Glyceria fluitans, Agropyron repens, Holcus lanatus, Bromus erectus, Agrostis stolonifera or Anthoxanthum odoratum.

5. f. sp. Glyceriae
6. f. sp. Agropyri
7. f. sp. Epigaei
8. f. sp. Holci
9. f. sp. Bromi

On Bromus erectus, erectus var. condensatus, inermis, sterilis, tectorum, secalinus, commutatus and apparently asper.

Between 1889 and 1918 a number of American workers have been concerned with the crown rust on oats though a uniform nomenclature has not been adopted.

Most of the American work has resulted from inoculation experiments with the use of urediniospores from oats.

Carleton (1899)[4] gives the following results of his experiments with the crown rust of oats, inoculating greenhouse seedlings with urediniospores:

Host	Result
Agropyron repens maritimum	Negative
Agrostis alba vulgaris	Negative
Aira caespitosa	Negative, only one or two spots
Alopecurus alpestris	Positive
Ammophila arenaria	Only one or two spots
Ammophila arundinacea	Negative
Andropogon halapense	Negative
Anthoxanthum odoratum	Negative, positive
Arrhenatherum elatius	Negative
Avena fatua	Positive
Avena hookeri	Doubtful
Avena sativa (various varieties)	Positive
Avena sativa nuda	Positive
Avena sativa orientalis	Positive
Avena sativa patula	Positive
Avena sterilis	Only one or two spots
Avena pratensis	Positive
Brachypodium distachys	Negative
Brizopyron siculum	Doubtful
Bromus unioloides	Negative
Dactylis glomerata	Positive, negative
Eatonia dudleyi	Negative
Eatonia obtusata	Negative
Eatonia sp. indet	Positive
Eleusine egyptiaca	Negative
Elymus virginicus	Negative
Eragrostis abyssinica	Negative
Eragrostis purshii	Negative
Festuca sp.	Positive
Holcus mollis	Doubtful
Hordeum jubatum	Negative
Hordeum murinum	Positive, only one or two spots
Koeleria cristata	Negative, positive
Lolium perenne	Negative
Panicum crus-galli	Negative
Phalaris arundinacea	Positive

Host	Result
Phalaris caroliniana	Negative
Phleum asperum	Positive
Phleum pratense	Positive
Poa annua	Only one or two spots
Poa pratensis	Negative
Polypogon monspeliensis	Positive
Schedonnardus paniculatus	Negative
Sporobolus asper	Negative
Sporobolus cryptandrus	Negative
Triodia cuprea	Negative
Trisetum subspicatum	Only one or two spots
Triticum spelta aestivum	Negative

Later experiments list Phalaris caroliniana and Arrhenatherum elatius as additional hosts.

Davis (1914)[7] adds Calamagrostis canadensis.

Reed, Hursch and Brentzel (1917)[30] worked with some 48 varieties of oats belonging to 9 species of Avena and found but one that showed any signs of resistance. Using urediniospores from oats, their inoculations on Arrhenatherum avenaceum, Holcus lanatus Festuca elatior, Lolium italicum and Lolium perenne were all unsuccessful.

Parker (1918)[18] carried on an extensive series of inoculations upon various agronomic oat varieties belonging to the groups Avena sativa and Avena sterilis, as well as upon numerous botanical races of Avena sativa and miscellaneous species of Avena. More detailed reference to this work will be made at another part of this paper.

The black stem rust of cereals so far has been divided into seven quite distinct biologic forms, each of them capable of infecting a relatively large number of grasses though in some cases somewhat closely confined to a few differential cereal hosts.

In the case of the crown rusts of oats and grasses at least 13 definite biologic forms have been established, not to mention cer-

tain unassigned forms, which in Europe, at least, are incapable of infecting a wide range of grass hosts. The form avenae is generally considered capable of infecting Avena alone.

The hosts listed by American workers have been given special attention for the reason that the host range seems to be less fixed in America than in Europe if we consider the form species established by European workers to be correct.

It is interesting in this connection to note that Grove (1913)[9] expresses the opinion, substantiated by Arthur (1918)[1] that the two forms of crown rust (P. coronata Cda. and P. lolii Niels or P. coronifera Kleb.) must be considered indifferentiable on a specific basis since host differences and a few minor morphological characters are the only distinguishing features.

All the forms of P. coronata Cda. together with those of P. coronifera Kleb. according to this view would be considered biologic forms of two races under the group name of P. coronata. Cda. All races of P. coronata Cda. in turn should be called P. Rhamni (Pers.) Wettst.

Despite the fact that no aecidial host infection experiments have been carried out in the present work, we have assumed that the form being used was none other than P. coronifera Kleb., for the following reason.

Rhamnus Frangula and Rhamnus cathartica, both naturalized European introductions, together with several indigenous species, are found in the United States. With but one exception (Pammel 1893),[17] though the American form of crown rust of oats has been shown to have its aecidial stage on other species of Rhamnus than Rhamnus cathartica, none of the American investigators have found

Rhamnus Frangula an aecidial host.

All workers, both foreign and domestic concur in the opinion that the form on oats belongs to the biologic form avenae.

Reference to the results of the present inoculation experiments however makes the fact evident that one of two conditions exists.

First, if the American form avenae is identical to that referred to by European writers, then its host range is certainly, under greenhouse conditions, by no means limited to Avena and far more extensive than is credited by European workers.

Second, the crown rust of oats in America, owing to the fact that its host range is more extensive than in Europe, and since it may cause infection on grasses serving as differential hosts for several of the biologic forms other than avenae, is plurivorous and may even be a separate biologic form not heretofore recognized.

Thoroughgoing aecidial host inoculation studies are needed to determine the part various species of Rhamnus and other possible aecidial hosts play in the crown rust problem in America.

The experimental work recorded in the present paper is divided into two parts; first, grass and cereal seedling inoculations and, second, spore germination studies.

It was thought that the various "strains" of the crown rust of oats might vary as to infection capabilities owing to possible sectional acclimitization. As the following tables show, material for inoculation purposes was obtained from Lynchburg, Virginia; Tallulah, Alabama; San Diego, California and University Farm, St. Paul, Minnesota.

The purpose of the inoculation experiments was to determine not only the grass and cereal hosts in general but whether these

hosts varied for the particular "strains" of rust from sections of the country where certain varieties of oats were commonly grown and where grasses of the region might be limited.

The spore germination studies were carried out to determine how long aeciospores and urediniospores would remain viable under varying conditions, and whether or not the teliospores would germinate without having overwintered.

Particular attention was paid to the conditions under which urediniospores developed by artificial inoculation in the greenhouse would remain viable and whether teliospores developed on oat seedlings in the greenhouse could be induced to germinate immediately.

METHODS AND MATERIALS

In the inoculation work on cereals and grasses, the results of which are presented in another part of this paper, the following methods and materials were used.

Urediniospores were smeared upon the outside surface of the outer seedling leaves by means of a flattened steel needle, previously sterilized in an alcohol flame. The seedling leaves were first moistened by an application of water, from a spray bulb, evenly distributed over the leaf surface by rubbing gently between the fingers. The implements used in the inoculation work are shown in Figure 1, Plate I.

The inoculated plants were allowed to remain for forty-eight hours in a pan of water, covered by a glass-topped metal moist chamber. See Figure 2, Plate I.

After removal from the moist chamber, the seedlings were placed upon a greenhouse bench and covered, during the summer, when it was necessary to open ventilators, with cages similar to those used to cover the seedlings previous to inoculation. See Fig. 1, Plate II.

The various strains of rust were separated by artificial barriers consisting of cages similar to those used in covering.

Previous to inoculation, the seedlings were grown in four-inch pots of a uniform soil mixture and under uniform conditions.

These seedlings were kept in a greenhouse in which no rusted plants were present. During the summer, when it was necessary to open ventilators, a cover, consisting of a cage of double muslin having a dead air space of about one inch between the two layers of cloth, was provided. See Figures 1 and 2, Plate II.

The grass seed from which seedlings used in the inoculation work herein recorded were grown, was obtained from the Minnesota and Montana Seed Laboratories. The seed of wheat, barley, rye and some of the oat varieties was secured from the Agronomy Division, University of Minnesota; the club wheat from the Washington Experiment Station at Pullman; various oat varieties were secured from the Alabama, California, Iowa and Virginia experiment stations.

Special methods and materials used in other phases of the present investigation will be discussed elsewhere.

EXPERIMENTAL RESULTS

Grass and Cereal Seedling Inoculations:

In the following tables the results of inoculations are indi-

cated by a fraction. The numerator indicates the total number of leaves inoculated. The denominator indicates the number of leaves that became infected. The number of leaves that became flecked but did not produce uredinia is indicated by the figure separated from the fraction by the semicolon.

In all subsequent tables Avena sativa indicates Ligowa oats, Minn. 381; Hordeum vulgare--Manchuria barley, Minn. 105; Secale cereale--Swedish rye, Minn. 3; Triticum compactum--Brown Gloria club wheat; Triticum vulgare--Haynes bluestem wheat, Minn. 169.

-------o-------

Table 1.

Summarized results of inoculations with urediniospores of various "strains" of Puccinia coronifera Kleb.

Plant Inoculated	Place of collection of rust and results of inoculations					
	Lynchburg, Virginia		San Diego, California	Tallulah, Alabama		St. Paul, Minnesota	
Agropyron caninum				0/23		1/26	Minute uredinia
Agropyron cristatum				0/44;10	Flecks distinct	0/37;12	Flecks fairly distinct
Agropyron desertorum				1/44;1	Minute uredinia; flecks indistinct	1/38;7	Minute uredinia; flecks distinct
Agropyron elongatum				0/8;2	Flecks indistinct	0/10;1	Flecks indistinct
Agropyron imbricatum				0/25;3	do.	0/13;2	do.
Agropyron intermedium				0/37;3	do.	2/17;9	Minute uredinia; flecks indistinct
Agropyron repens	0/40			0/37		0/12	
Agropyron smithii				0/9;7	Flecks distinct	0/38;3	Extensive dead areas
Agropyron tenerum				0/7		0/16	
Agrostis alba				0/27		0/532	•

Table 1 - Continued

Plant Inoculated	Place of collection of rust and results of inoculations							
	Lynchburg, Virginia		San Diego, California		Tallulah, Alabama		St. Paul, Minnesota	
Agrostis canina					0/3		0/10	
Agrostis stolonifera					0/30		0/35	
Alopecurus geniculatus					0/51;36	Flecks distinct	164/569;8	*Moderate uredinia; distinct flecks
Alopecurus pratensis			0/10		0/15;3	Flecks indistinct	3/166;20	*Minute uredinia; distinct whitened areas
Andropogon furcatus					0/4		0/13	
Anthoxanthum odoratum					1/41;26	Moderate uredinia; flecks distinct	7/61;42	Moderate uredinia; distinct flecks
Arrhenatherum elatius	0/16;3	Flecks indistinct			0/33		1/72	*Minute uredinia
Avena fatua	9/9	Heavy	9/9	Heavy			30/42	*Moderate uredinia
Avena sativa	135/150	do.	128/155	do.	739/771;1	Heavy; pigment	741/902;3	*Heavy; pigment; telia
Avena sterilis	11/13	do.	5/7	do.	27/29	Uredinia scattered; heavily infected leaves yellowed	21/21	Minute uredinia; large white dead areas; telia; pigment; some leaves heavy
Bouteloua curtipendula							0/13	

Table 1 - Continued

Plant Inoculated	Place of collection of rust and results of inoculations							
	Lynchburg, Virginia		San Diego, California		Tallulah, Alabama		St. Paul, Minnesota	
Briza maxima					0/7		0/5	Large areas of leaves killed
Bromus ciliatus							0/61;17	*
Bromus erectus	0/8				0/11;4	Flecks distinct	1/45	*Minute uredinia
Bromus inermis	0/10				0/15;5	do	1/52	* do.
Bromus japonicus	1/15;1	Minute uredinia			0/23;3	Flecks indistinct	0/87;4	*Flecks indistinct
Bromus purgans							0/23	*
Bromus tectorum	0/12		0/19				1/133;13	*Minute uredinia
Calamagrostis canadensis					0/3;2	do.		
Cynosurus cristatus					0/12		0/31;2	Flecks indistinct
Dactylis glomerata							16/32;1	Moderately heavy
Danthonia spicat					0/22		0/23	

Table 1 – Continued

Plant Inoculated	Place of collection of rust and results of inoculations							
	Lynchburg, Virginia		San Diego, California		Tallulah, Alabama		St. Paul, Minnesota	
Elymus canadensis	0/35		0/13;6	Flecks distinct	0/7;4	Flecks indistinct	0/35;19	Flecks distinct
Elymus robustus	0/11;5	Flecks indistinct	0/18		0/15;4	Flecks distinct, numerous	2/15;8	Moderate uredinia; telia
Elymus virginicus	0/5						0/10	
Festuca elatior					0/4		0/83	
Festuca heterophylla					0/16		0/242;15	*Flecks indistinct
Festuca ovina			0/45		0/36		2/58;6	Minute uredinia; flecks indistinct
Festuca pratensis					0/38		0/72	
Festuca rubra					0/24		1/136;38	do.
Holcus lanatus			0/13		0/52		3/71;3	do.
Hordeum jubatum	0/18;3	Flecks distinct					1/20;6	Minute uredinia; flecks distinct
Hordeum pusillum	9/14	Moderate uredinia			0/25;32	Flecks distinct	6/55;35	Moderate uredinia; flecks distinct

Table 1 - Continued

Plant Inoculated	Place of collection of rust and results of inoculations							
	Lynchburg, Virginia		San Diego, California		Tallulah, Alabama		St. Paul, Minnesota	
Hordeum vulgare	0/10;9	Flecks distinct			0/35;10	Flecks distinct	3/38;6	*Very minute uredinia; flecks distinct
Lolium italicum	0/14		0/12		0/39;3	Flecks indistinct	0/54	*
Lolium perenne	0/7		0/8		0/10		0/45	
Lolium temulentum	0/17		0/12;3	Flecks indistinct	0/39;35	Flecks distinct	9/69;37	Minute uredinia; dead, colorless areas extensive; very hypersensitive
Phalaris canariensis					0/9		0/28	
Phleum pratense			0/15		14/35;20	Moderate; distinct flecks	16/30;14	Heavy; distinct flecks
Phragmites communis					0/12			
Poa annua					0/38;36	Flecks distinct	0/37;36	Flecks distinct
Savastana odorata					0/10			
" cereale	0/14;10	do.			0/33;9	do.	0/64;10	do.

Table 1 - Continued

Plant Inoculated	Place of collection of rust and results of inoculations							
	Lynchburg, Virginia		San Diego, California		Tallulah, Alabama		St. Paul, Minnesota.	
Triticum compactum	0/17;11	Flecks distinct			0/31;15	Flecks distinct	0/37;5	Flecks distinct
Triticum vulgare	0/10				0/33;9	do.	0/28;3	do.
Alabama, Appler 617					12/13	Heavy; pigment	6/12;6	Uredinia few, scattered; dead, colorless areas; telia in abundance
Alabama, Burt-Spring strain					11/12	do.	5/7	Uredinia minute; large, white dead areas; telia
Alabama, Fulghum 313					19/19	do.	13/14	Heavy; pigment
Alabama, Red Rust Proof - spring strain					16/17	do.	10/19;1	Heavy
California, Oklahoma Red Rust Proof					13/15	do.	9/9	Heavy; telia
California, Texas Red Rust Proof					10/10	do.	13/13	Heavy
Iowa 73					6/15;9	Uredinia few, scattered; white hypersensitive areas	7/11;4	Uredinia few, scattered; white hypersensitive areas

Table 1 - Continued

Plant Inoculated	Place of collection of rust and results of inoculations							
	Lynchburg, Virginia		San Diego, California		Tallulah, Alabama		St. Paul, Minnesota	
Iowa 96					0/7;7	White hypersensitive areas	8/10;2	Uredinia few, scattered; white hypersensitive areas
Iowa 101½					11/13;3	Most leaves heavy; few leaves--scattered uredinia; white hypersensitive areas	14/14	Most leaves heavy; few leaves with few uredinia and white hypersensitive areas
Iowa 102½					3/6;4	do.	16/16	do.
Iowa 103, Minn. 531					26/26	Heavy; pigment	28/28	Heavy; telia
Iowa 115					12/12	Heavy	7/7	Heavy
Minnesota, Golden Rain 528					29/29	do.	12/12	Heavy; white areas among uredinia; telia
Minnesota, Joonette 550					14/14	Heavy; pigment	16/16	Heavy
Minnesota, Red Rust Proof 538					16/16	Heavy	14/14	do.
Minnesota, Silver Mine 506					14/14	Heavy; pigment	18/18	do.

Table 1 - Continued

Plant Inoculated	Place of collection of rust and results of inoculations					
	Lynchburg, Virginia		San Diego, California		Tallulah, Alabama	St. Paul, Minnesota
Minnesota, Swedish Crown 526					24/24 Heavy	14/14 Heavy; telia
Minnesota, Victory 514					19/23 Heavy; pigment	13/13 do.
Minnesota, White Russian					26/26 do.	12/12 Heavy; pigment
Minnesota 261					21/21 do.	20/23 do.
Minnesota 281					23/23 do.	27/27 Heavy; telia
Minnesota 512					22/22 do.	20/20 Heavy
Virginia, Burt					14/14 do.	9/13 Heavy; telia
Virginia, Swedish Select					13/13 do.	7/14 do.
Virginia, Texas Red Rust Proof					8/13 Heavy	14/14 do.

* In some of the trials, urediniospores were applied in water suspension by means of an atomizer.

1. It is apparent that under greenhouse conditions the Lynchburg, Virginia "strain" of P. coronifera Kleb., readily infects Avena fatua L., Avena sativa L., Avena sterilis L., Hordeum pusillum Nutt., moderately and Bromus japonicus Thunb., very weakly.

Arrhenatherum elatius (L.) Beauv., Elymus robustus Scribn. and J. G. Sm., Hordeum jubatum L., Hordeum vulgare L., Secale cereale L., and Triticum compactum Host., were certainly resistant as evidenced by the absence of uredinia and the presence of more or less definite flecks.

Agropyron repens (L.) Beauv., Bromus erectus Huds., Bromus inermus Leyss., Bromus tectorum L., Elymus canadensis L., Elymus virginicus L., Lolium italicum R. Br., Lolium perenne L., Lolium temulentum L., and Triticum vulgare Vill., appeared to be entirely immune.

2. Under greenhouse conditions, the San Diego, California "strain" of P. coronifera Kleb., infects Avena fatua L., Avena sativa L., and Avena sterilis L., heavily.

Elymus canadensis L., and Lolium temulentum L., seem to be resistant, while Alopecurus pratensis L., Bromus tectorum L., Elymus robustus Scribn. and J. G. Sm., Festuca ovina L., Holcus lanatus L., Lolium italicum L., Lolium perenne L., and Phleum pratense L., appear to be immune.

3. The Tallulah, Alabama, "strain" of P. coronifera Kleb., under greenhouse conditions infects Avena sativa L., Avena sterilis L., and Phleum pratense L., heavily as well as the following agronomic varieties of cultivated oats: Alabama-Appler 617; Alabama-Burt, spring strain; Alabama-Red Rust Proof, spring strain; Alabama-

Fulghum 313; California--Oklahoma Red Rust Proof; Texas Red Rust Proof; Iowa--101½; 102½; 103, Minn. 531; 115; Minnesota--Golden Rain 528; Joonette 550; Red Rust Proof 538; Silver Mine 506; Swedish Crown 526; Victory 514; White Russian; 361; 381; 512; Virginia--Burt; Swedish Select; Texas Red Rust Proof.

Agropyron desertorum Schult., Anthoxanthum odoratum L., was only weakly infected while Agropyron cristatum J. Gaert., Agropyron elongatum Host., Agropyron imbricatum Roem. and Schult., Agropyron intermedium Beauv., Agropyron Smithii Rydb., Alopecurus geniculatus L., Alopecurus pratensis L., Bromus erectus Huds., Bromus inermis Leyss., Bromus japonicus Thunb., Calamagrostis canadensis (Michx.) Beauv., Elymus canadensis L., Elymus robustus Scribn. and J.G.Sm., Hordeum pusillum Nutt., Hordeum vulgare L., Lolium italicum R. Br., Lolium temulentum L., Poa annua L., Secale cereale L., Triticum compactum Host., and Triticum vulgare Vill., seem to be resistant owing to the absence of any uredinia and the presence of more or less distinct flecks.

Agropyron caninum (L.) Beauv., Agropyron repens (L.) Beauv., Agropyron tenerum Vasey, Agrostis alba L., Agrostis canina L., Agrostis stolonifera Vasey, Andropogon furcatus Fuhl., Arrhenatherum elatius (L.) Beauv., Briza maxima L., Cynosurus cristatus L., Danthonia spicata (L.) Beauv., Festuca elatior L., Festuca heterophylla (Lam.) Hack., Festuca ovina L., Festuca pratensis Huds., Festuca rubra L., Holcus lanatus L., Lolium perenne L., Phalaris canariensis L., Phragmites communis Trin.,and Savastana odorata (L.) Scribn., all seemed to be immune.

4. The University Farm, St. Paul, Minnesota "strain" of P. coro-

nifera Kleb., under greenhouse conditions readily infects Avena sativa L., and Phleum pratense L., as well as the following agronomic varieties of oats: Alabama--Fulghum 313; Red Rust Proof, spring strain; California--Oklahoma Red Rust Proof; Texas Red Rust Proof; Iowa--103, Minn. 531; 115; Minnesota--Golden Rain 528; Joonette 550; Red Rust Proof 538; Silver Mine 506; Swedish Crown 526; Victory 514; White Russian; 261; 281; 512; Virginia--Burt; Swedish Select; Texas Red Rust Proof.

Alopecurus geniculatus L., Anthoxanthum odoratum L., Avena fatua L., Dactylis glomerata L., Elymus robustus Scribn. and J.G. Sm., Hordeum pusillum Nutt., are but moderately infected together with the agronomic oat varieties--Iowa--101½; 102½.

Agropyron caninum (L.) Beauv., Agropyron desertorum Schult., Agropyron intermedium Beauv., Alopecurus pratensis L., Arrhenatherum elatius (L.) Beauv., Avena sterilis L., Bromus erectus Huds., Bromus inermis Leyss., Bromus tectorum L., Festuca ovina L., Festuca rubra L., Holcus lanatus L., Hordeum jubatum L., Hordeum vulgare L., Lolium temulentum L., and the agronomic oat varieties--Alabama--Appler 617; Burt, spring strain; Iowa--73 and 96 are only weakly infected while Agropyron cristatum J. Gaert., Agropyron elongatum Host., Agropyron imbricatum Roem. and Schult., Agropyron smithii Rydb., Bromus ciliatus L., Bromus japonicus L., Cynosurus cristatus L., Elymus canadensis L., Festuca heterophylla (Lam.) Hack., Poa annua L., Secale cereale L., Triticum compactum Host., and Triticum vulgare Vill., seem to be resistant as evidenced by the absence of uredinia and the production of more or less definite flecks.

Agropyron repens (L.) Beauv., Agropyron tenerum Vasey,

Agrostis alba L., Agrostis canina L., Agrostis stolonifera Vasey, Andropogon furcatus Muhl., Bouteloua curtipendula (Michx.) Torr., Briza maxima L., Bromus purgans L., Danthonia spicata (L.) Beauv., Elymus virginicus L., Festuca elatior L., Festuca pratensis Huds., Lolium italicum R. Br., Lolium perenne L., Phalaris canariensis L., seem to be immune.

5. (N.B. For convenience in discussion, "strains" will be referred to by numbers: 1--Lynchburg, Virginia. 2--San Diego, California. 3--Tallulah, Alabama. 4--St. Paul, Minnesota.)

"Strain" 4 infects Agropyron caninum (L.) Beauv., Agropyron intermedium Beauv., and Alopecurus geniculatus L., while "strain" 3 does not, nor does "strain" 1 in the case of Arrhenatherum elatius (L.) Beauv., Bromus erectus Huds., and Bromus inermis Leyss.

"Strain" 1 infects Bromus japonicus L., but "strains" 3 and 4 do not.

"Strain" 4 infects Bromus tectorum L., but "strains" 1 and 2 do not. A like condition exists for Elymus robustus Scribn. and J.G.Sm., where "strain" 3 also gave negative results. "Strain" 4 infected Festuca ovina L., Holcus lanatus L., but "strains" 2 and 3 did not.

"Strain" 4 infected Hordeum jubatum L.; "strain"1 did not.

"Strain" 4 infected Lolium temulentum L.; "strains" 1, 2 and 3 did not.

Phleum pratense L., was infected by "strains" 3 and 4 but not by "strain" 2.

"Strain" 4 infected Iowa 96, oats, but "strain" 3 did not.

Other grasses or oat varieties inoculated were either common hosts to the several "strains" used or else remained uninfected

by any of them. Although the lists of hosts and characters of infection are by no means identical for the four "strains" of rust used in the inoculation work, the differences are, owing in most cases to very weak infection, not very striking nor always consistent.

In the absence of more extensive work and more complete data, therefore, a definite statement as to variations in infection capabilities between these four "strains" of rust is purposely avoided.

It has been considered of possible significance to compare the summarized results of urediniospore inoculations with all the "strains" of P. coronifera Kleb., with those obtained for P. graminis avenae Eriks. and Henn., by Stakman and Piemeisel (1917)[21], since the work was carried out under similar environmental conditions and by means of somewhat similar technic and upon grass seedlings grown in most cases from the same seed lots.

----o----

Table 2

Comparative results of urediniospore inoculations with P. coronifera Kleb., and P. graminis avenae Erikss. and Henn.

Plant Inoculated	Results of Inoculations			
	P. coronifera Kleb.		P. graminis avenae Erikss. and Henn.	
Agropyron caninum	1/49	Minute uredinia	0/61	
Agropyron cristatum	0/81; 22	Flecks fairly distinct	3/25	
Agropyron desertorum	2/83; 8	Minute uredinia; flecks fairly distimct	0/30	
Agropyron elongatum	0/18; 3	Flecks indistinct	0/25	
Agropyron imbricatum	0/38; 5	do.	0/20	
Agropyron intermedium	2/54; 12	Minute uredinia; flecks indistinct	0/25	
Agropyron repens	0/49		0/98	
Agropyron smithii	0/47; 10	Flecks distinct; extensive dead areas	0/54	
Agropyron tenerum	0/23		0/35	
Agrostis alba	0/559	*	37/510	Light to moderate
Agrostis stolonifera	0/65		26/273	Light to moderate; strong flecks
Alopecurus geniculatus	164/620; 8	Moderate uredinia; flecks distinct*	57/77	Moderate
Alopecurus pratensis	3/191; 23	Minute uredinia; distinct whitened areas*	154/200	Moderate to heavy

Table 2 - Continued

Plant Inoculated	Results of Inoculations			
	P. coronifera Kleb.		P. graminis avenae Eriks. and Henn.	
Anthoxanthum odoratum	8/102;68	Moderate uredinia; flecks distinct	76/183	Moderate
Arrhenatherum elatius	1/121;3	Minute uredinia;* flecks indistinct	19/211	Light to moderate
Avena fatua	48/60	Heavy*	83/84	Heavy
Bromus erectus	1/64;4	Minute uredinia; flecks distinct*	3/35	Light
Bromus inermis	1/77;5	do.	0/40	
Bromus purgans	0/23	*	1/23	do.
Bromus tectorum	1/164;13	*Minute uredinia	194/194	Light to moderate
Calamagrostis canadensis	0/3;2	Flecks indistinct	34/65	Moderate
Cynosurus cristatus	0/43;2	do.	0/90	
Dactylis glomerata	16/32;1	Moderately heavy	70/98	Heavy
Danthonia spicata	0/45		0/36	
Elymus canadensis	0/80;29	Flecks distinct	16/285	Small uredinia; weak
Elymus robustus	2/59;17	Moderate uredinia; telia; flecks distinct	4/158	Small uredinia.
Elymus virginicus	0/15		0/160	
Festuca elatior	0/87		13/184	Weak
Festuca ovina	2/139;6	Minute uredinia; flecks indistinct	4/54	Moderate

Table 2 - Continued

Plant Inoculated	Results of Inoculations			
	P. coronifera Kleb.		P. graminis avenae Erikss. and Henn.	
Festuca rubra	1/150;38	Minute uredinia; flecks indistinct	0/75	
Holcus lanatus	3/135;12	do.	81/233	Moderate; small uredinia
Hordeum jubatum	1/38;9	Minute uredinia; flecks distinct	0/55	
Hordeum pusillum	15/94;47	Moderate uredinia; flecks distinct	4/38	Small uredinia
Hordeum vulgare	3/73;35	*Very minute uredinia; flecks distinct	69/678	Moderate to heavy; minute uredinia
Lolium italicum	0/109;2	Flecks indistinct*	2/173	Weak
Lolium perenne	0/70		5/191	do.
Lolium temulentum	9/127;54	Minute uredinia; dead colorless areas extensive; very hypersensitive	16/55	Moderate
Phalaris canariensis	0/37		17/19	do.
Phleum pratense	30/80;34	Moderately heavy; flecks distinct	16/186	Weak
Savastana odorata	0/10		0/21	
Secale cereale	0/111;29	Flecks distinct	21/413;3	Minute uredinia
Triticum vulgare	0/69;12	do.	0/457	

Common hosts established for both P. coronifera Kleb., and P. graminis avenae Erikss. and Henn., are: Alopecurus geniculatus L., Alopecurus pratensis L., Anthoxanthum odoratum L., Arrhenatherum elatius (L.) Beauv., Avena fatua L., Bromus erectus Huds., Bromus tectorum L., Dactylis glomerata L., Elymus robustus Scribn. and J.G.Sm., Festuca ovina L., Holcus lanatus L., Hordeum pusillum Nutt., Hordeum vulgare L., Lolium temulentum L., and Phleum pratense L.

Agropyron caninum (L.) Beauv., Agropyron desertorum Schult., Agropyron intermedium Beauv., Bromus inermis Leyss., Festuca rubra L., and Hordeum jubatum L., serve as hosts for P. coronifera Kleb. but not for P. graminis avenae Erikss. and Henn.

On the other hand Agropyron cristatum J. Gaert., Agrostis alba L., Agrostis stolonifera Vasey, Bromus purgans L., Calamagrostis canadensis (Michx.) Beauv., Elymus canadensis L., Festuca elatior L., Lolium italicum R. Br., Lolium perenne L., Phalaris canariensis L., and Secale cereale L., are hosts for P. graminis avenae Erikss. and Henn., but not for P. coronifera Kleb.

Spore germination studies:

Considerable work has already been done on the spore germination of crown rust of oats.

Christman (1902-3)[5] found under Wisconsin conditions, viable urediniospores at any time during the winter with a three months' period in which the temperature hovered about the freezing point.

Urediniospores from oats developed upon protected plants during the winter, germinated as late as January 26th. Indications were

that the mycelium would be as resistant as the host upon which it grew.

Old spores remained viable for some time though new crops of spores from overwintered mycelium seemed the more important mode of spring infection.

Reed and Holmes (1911-12)[19] found viable urediniospores on oats throughout the year under Virginia conditions. They conclude that the crown rust on oats has an enduring mycelium capable of producing a new crop of spores during much of the winter and though spore production ceased during mid-winter, the mycelium, upon the advent of warm weather, was capable of producing new crops of viable spores.

Results of spore germination studies in the present work are recorded in the following pages:

--------0--------

Table 3.

Aeciospore germination studies of P. coronifera Kleb.

No.	Host	Date Collected	Place	Germination *
1.	Rhamnus sp.	6-23-17	Montevideo, Minn.	1-9-17 to 1-12-17 None
2.	do.	6-26-17	Wahpeton, N. Dak.	12-10-17 to 12-13-17 None
3.	do.	do.	Brookings, S.Dak.	1-9-17 to 1-12-17 None
4.	Rhamnus cathartica	do.	do.	do.
5.	do.	6-27-17	Moorhead, Minn.	12-10-17 to 12-13-17 None
6.	do.	6-28-17	Aberdeen, S. Dak.	1-13-18 to 1-16-18 None
7.	do.	6-29-17	do.	do.
8.	Rhamnus sp.	7-11-17	Beaver Dam, Wis.	12-10-17 to 12-13-17 None

* Hanging drops of water in Van Tieghem cells.

The results recorded above indicate that aeciospores, after a minimum period of six months, in which they became thoroughly dried, were incapable of germination.

Table 4.

Urediniospore germination studies of P. coronifera Kleb.

No.	Place Collected	Locality Germinated	Temperature		Germination[1]	Date
			Max.	Min.		
1.	Greenhouse, Univ. Farm, St. Paul, Minn.	Ice Box	10°C.	7°C.	2%	1-21-1 to 1-27-18
2.	do.	Bell Jar[2]	14.5°C.	14°C.	1%	1-28-18 to 1-31-18
3.	do.	Room	20.5°C.	14°C.	50%	do.
4.	do.	do.	21.5°C.	13°C.	10%	1-21-18 to 1-27-18
5.	do.	Incubator	25°C.	25°C.	25%	1-28-18 to 1-31-18
6.	do.	do.	32°C.	31°C.	None	do.

N.B.1. Hanging drops of water in Van Tieghem cells.

2. Cells placed under bell jar in which temperature was reduced by running water applied to outside.

These results show that urediniospores are capable of germination at relatively low temperatures though apparently not above 32°C. A temperature of about 18°C. seems to be the optimum. Johnson (1912)[10] comes to similar conclusions. He gives 7° to 8°C. as the minimum, 30° C. as the maximum, and 12° to 17°C. as the optimum.

Table 5.

Urediniospore germination studies of P. coronifera Kleb.

No.	Host	Date Collected	Place	Germination *
1.	Holcus lanatus	4-26-17	Corvallis, Ore.	11-20-17 to 11-23-18 None
2.	Avena sativa	5-7-17	San Antonio, Tex	1-13-18 to 1-16-18 None
3.	Avena fatua	5-15-17	San Diego, Cal.	11-20-17 to 11-23-18 None
4.	do.	5-16-17	Santa Barbara, Cal.	do.
5.	Avena sativa (volunteer)	do.	Beaumont, Tex.	1-9-18 to 1-12-18 None
6.	do.	do.	do.	do.
7.	Avena sativa	5-17-17	do.	1-10-18 to 1-13-18 None
8.	Holcus lanatus	5-21-17	Corvallis, Ore.	11-20-17 to 11-23-17 None
9.	Avena sativa	5-30-17	Shreveport, La.	1-9-18 to 1-12-18 None
10.	do.	7-9-17	Madison, Wis.	12-10-17 to 12-13-17 None
11.	do.	7-17-17	Brookings, S.D.	1-13-18 to 1-16-18 None
12.	do.	do.	do.	do.
13.	do.	do.	Carrol, Iowa.	do.
14.	do.	7-18-17	Missouri Valley, Iowa.	do.
15.	do.	do.	Bushnell, S.D.	do.
16.	do.	7-19-17	Pipestone, Minn.	do.

Table 5 - Continued

No.	Host	Date Collected	Place	Germination *
17.	Avena sativa	7-20-17	Onawa, Iowa.	1-13-18 to 1-16-18 None
18.	do.	do.	Pipestone, Minn.	1-9-18 to 1-12-18 None
19.	do.	7-21-17	Sioux City, Ia.	1-13-18 to 1-16-18 None
20.	do.	do.	Belle Plaine, Minn.	do.
21.	do.	7-31-17	Albert Lea, Minn.	12-10-17 to 12-13-18 None
22.	do.	8-1-17	Lynchburg, Va.	11-20-17 to 11-24-17 None
23.	do.	do.	do.	11-20-17 to 11-23-17 None
24.	do.	8-3-17	Spring Valley, Minn.	12-10-17 to 12-12-17 None
25.	do.	8-5-17	Preston, Minn.	1-13-18 to 1-16-18 None
26.	do.	8-6-17	Caledonia, Minn.	12-10-17 to 12-13-18 None
27.	do.	do.	Lexington, Ky.	11-20-17 to 11-24-17 None
28.	do.	do.	do.	do.
29.	do.	8/11/17	Zumbrota, Minn.	12-10-17 to 12-13-17 None
30.	do.	8/14/17	Wabasha, Minn.	do.
31.	do.	do.	do.	do.
32.	do.	8/15/17	Pembina, N.Dak.	1-13-18 to 1-16-18 None
33.	do.	8-24-17	Granite Falls, Minn.	do.

Table 5 - Continued

No.	Host	Date Collected	Place	Germination *
34.	Avena sativa	8-25-17	Univ. Farm, Minn.	11-20-17 to 11-23-17 Slight
35.	do.	8-28-17	do.	11-20-17 to 11-24-17 None
36.	do.	8-29-17	do.	do.
37.	Avena sterilis	do.	do.	do.
38.	Avena sativa	8-31-17	Sauk Center, Minn.	1-13-18 to 1-16-18 None
39.	do.	9-7-17	Hinckley, Minn.	1-10-18 to 1-13-18 None
40.	do.	9-15-17	Two Harbors, Minn.	12-10-17 to 12-13-17 None
41.	do.	9-17-17	Virginia, Minn.	1-10-18 to 1-13-18 None
42.	do.	9-24-17	Univ.Farm, Minn.	11-20-17 to 11-23-17 None
43.	Avena sterilis	do.	do.	do.
44.	Avena fatua	9-28-17	do.	9-28-17 Good
45.	Calamagrostis canadensis	10-5-17	Wayzata, Minn.	11-20-17 to 11-23-17 None
46.	Avena sativa	10-8-17	Springfield, Mo.	1-9-18 to 1-12-18 None
47.	do.	10-23-17	Gilliam, La.	11-20-17 to 11-22-17 Slight
48.	do.	10-30-17	Jackson, Tenn.	do.
49.	do.	do.	Springfield, Mo.	11-20-17 to 11-23-17 None
50.	do.	11-1-17	Sedalia, Mo.	11-20-17 to 11-24-17 None
51.	do.	do.	Nashville, Tenn.	do.

Table 5 - Continued

No.	Host	Date Collected	Place	Germination *
52.	Avena sativa	11-4-17	Knoxville, Tenn.	11-20-17 to 11-23-17 Fair
53.	do.	11-6-17	Lexington, Ky.	11-20-17 to 11-24-17 Fair
54.	do.	11-14-17	Univ.Farm, Minn.	11-14-17 to 11-24-17 None
55.	do.	11-29-17	Newell, S. Dak.	12-15-17 to 12-16-17 50%
56.	do.	12-15-17	Knoxville, Tenn.	1-19-18 to 1-22-18 None

* Hanging drops of water in Van Tieghem cells.

Urediniospores of P. coronifera Kleb., from Avena sativa are shown to be viable 14, 16, 20, 27 and 87 days after collection.

Table 6.

Teliospore germination studies of Puccinia coronifera Kleb.

No.	Host	Date	Place	Germination *
1.	Avena sativa	8-9-17	Rochester, Minn.	3-26-18 to 3-19-18 None
2.	do.	do.	do.	3-21-18 to 4-3-18 None
3.	do.	5-19-17	Baton Rouge, La.	do.
4.	do.	8-22-17	Olivia, Minn.	do.
5.	Avena sterilis	1-8-18	Univ. Farm, Minn.	do.
6.	do.	1-14-18	do.	do.
7.	do.	2-8-18	do.	do.
8.	do.	3-25-18	do.	3-25-18 to 3-30-18 None
9.	do.	4-3-18	do.	4-3-18 to 4-8-18 None
10.	do.	5-2-18	do.	5-2-18 to 5-5-18 None

* Hanging drops of water in Van Tieghem cells.

It is evident that, previous to over-wintering, and as late in the spring as May 2, teliospores of P. coronifera Kleb., are not capable of germination.

Urediniospore germination studies of *Puccinia coronifera* Kleb.

Series 1.

a. *P. coronifera* Kleb., from *Avena sativa*, Field, University Farm, Minnesota, 9-24-17, O_5. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. The petri dish was placed outside on 12-11-17 and protected by covering with about one foot of leaves and snow. Twenty-four hour germination test on 12-11-17 showed spores to be viable.

b. *P. coronifera* Kleb., from *Avena sativa*, Field, University Farm, Minnesota, 9-24-17, O_5. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed outside on 12-11-17 and not afforded any protection. Twenty-four hour germination test on 12-11-17 showed spores to be viable.

c. *P. coronifera* Kleb., from *Avena sterilis*, Field, University Farm, Minnesota, 9-24-17, O_5. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was wrapped in heavy manilla paper and placed in a dark cabinet drawer, inside on 12-11-17. Twenty-four hour germination test on 12-11-17 showed spores to be viable.

d. *P. coronifera* Kleb., from *Avena sterilis*, Field, University Farm, Minnesota, 9-24-17, O_3 *Avena sterilis* $1O_3$. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed in a room fully exposed to sunlight, on 12-11-17. Twenty-four hour germination test on 12-11-17 showed the spores to be viable.

Series 2.

a. P. coronifera Kleb., from volunteer oats, Lynchburg, Va., 8-1-17, 0_5 Avena sterilis $_1 0_2$ Avena sterilis $_1$. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed outside on 12-18-17 and protected by covering with about a foot of leaves and snow. Twenty-four hour germination test on 12-18-17 showed spores to be viable.

b. P. coronifera Kleb., from volunteer oats, Lynchburg, Va., 8-1-17, 0_5 Avena fatua $_1 0_2$. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed outside on 12-18-17 and not afforded any protection. Twenty-four hour germination test on 12-18-17 showed spores to be viable.

Series 3.

a. P. coronifera Kleb., from Avena fatua, San Diego, Cal., 5-15-17, 0_{13}. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed outside on 12-13-17 and protected by covering with about a foot of leaves and snow. Twenty-four hour germination test on 12-13-17 showed spores to be viable.

b. P. coronifera Kleb., from Avena fatua, San Diego, Cal., 5-15-17, 0_{13}. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was then placed outside on 12-13-17 and not afforded any pro-

tection. Twenty-four hour spore germination test on 12-13-17 showed spores to be viable.

Series 4.

a. P. coronifera Kleb., from Avena sativa, Tallulah, Ala., 5-25-17, O_{13}. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed outside on 12-13-17 and protected by covering with about a foot of leaves and snow. Twenty-four hour germination test on 12-13-17 showed spores to be viable.

b. P. coronifera Kleb., from Avena sativa, Tallulah, Ala., 5-25-17, O_{13}. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed outside on 12-13-17 and not afforded any protection. Twenty-four hour germination test showed the spores to be viable.

c. P. coronifera Kleb., from Avena sativa, Tallulah, Ala., 5-25-17, O_{13}. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was wrapped in heavy manilla paper and placed in a dark cabinet drawer, inside on 12-13-17. Twenty-four hour germination test on 12-13-17 showed spores to be viable.

d. P. coronifera Kleb., from Avena sativa, Tallulah, Ala., 5-25-17, O_{13}. Several leaves cut from rusted plant grown in the greenhouse and placed in a petri dish. This petri dish was placed in a room fully exposed to sunlight, on 12-13-17. Twenty-four hour germination test on 12-13-17 showed spores to be viable.

Table 7.

Urediniospore germination studies of P. coronifera Kleb.

Series No.	Date of Exposure	Range of Temperature		Germination*
		Max.	Min.	
1a	12-11-17 to 1-7-18	42°F.	-26°F.	None
1a	do. to 1-18-18	42°F.	-26°F.	do.
1a	do. to 1-31-18	42°F.	-27°F.	do.
1a	do. to 2-6-18	42°F.	-27°F.	do.
1a	do. to 2-26-18	42°F.	-27°F.	do.
2a	12-18-17 to 1-7-18	42°F.	-26°F.	4%
2a	do. to 1-18-18	42°F.	-26°F.	4%
2a	do. to 1-31-18	42°F.	-27°F.	1%
2a	do. to 2-6-18	42°F.	-27°F.	None
2a	do. to 2-26-18	42°F.	-27°F.	do.
3a	12-13-17 to 1-7-18	42°F.	-26°F.	do.
3a	do. to 1-18-18	42°F.	-26°F.	do.
3a	do. to 1-31-18	42°F.	-27°F.	do.
3a	do. to 2-6-18	42°F.	-27°F.	do.

Table 7 - Continued

Series No.	Date of Exposure	Range of Temperature		Germination*
		Max.	Min.	
3a	12-13-17 to 2-26-18	42°F.	-27°F.	None
4a	do. to 1-7-18	42°F.	-26°F.	do.
4a	do. to 1-18-18	42°F.	-26°F.	do.
4a	do. to 1-31-18	42°F.	-27°F.	do.
4a	do. to 2-6-18	42°F.	-27°F.	do.
4a	do. to 2-26-18	42°F.	-27°F.	do.
1b	12-11-17 to 1-3-18	42°F.	-26°F.	do.
1b	do. to 1-19-18	42°F.	-26°F.	do.
1b	do. to 1-31-18	42°F.	-27°F.	do.
1b	do. to 2-6-18	42°F.	-27°F.	do.
1b	do. to 2-22-18	42°F.	-27°F.	do.
2b	do. to 1-3-18	42°F.	-26°F.	do.
2b	do. to 1-19-18	42°F.	-26°F.	do.
2b	12-11-17 to 1-31-18	42°F.	-27°F.	do.
2b	do. to 2-6-18	42°F.	-27°F.	do.

Table 7 - Continued

Series No.	Date of Exposure	Range of Temperature		Germination*
		Max.	Min.	
2b.	12-11-17 to 2-22-18	42°F.	-27°F.	None
3b	12-13-17 to 1-3-18	42°F.	-26°F.	do.
3b	do. to 1-19-18	42°F.	-26°F.	do.
3b	do. to 1-31-18	42°F.	-27°F.	do.
3b	do. to 2-6-18	42°F.	-27°F.	do.
3b	do. to 2-22-18	42°F.	-27°F.	do.
3b	do. to 2-22-18	42°F.	-27°F.	do.
4b	do. to 1-3-18	42°F.	-26°F.	do.
4b	do. to 1-19-18	42°F.	-26°F.	do.
4b	do. to 1-31-18	42°F.	-27°F.	do.
4b	do. to 2-6-18	42°F.	-27°F.	do.
4b	do. to 2-22-18	42°F.	-27°F.	do.
1c	12-11-17 to 1-3-18	86°F.	29°F.	1%
1c	do. to 1-19-18	86°F.	29°F.	1%
1c	do. to 1-31-18	86°F.	29°F.	25%

Table 7 - Continued

Series No.	Date of Exposure	Range of Temperature		Germination*
		Max.	Min.	
1c	12-11-17 to 2-6-18	86°F.	29°F.	2%
1c	do. to 2-19-18	86°F.	29°F.	1%
1c	do. to 2-28-18	86°F.	29°F.	1%
4c	12-13-17 to 1-3-18	86°F.	29°F.	30%
4c	do. to 1-18-18	86°F.	29°F.	1%
4c	do. to 1-31-18	86°F.	29°F.	None
4c	do. to 2-6-18	86°F.	29°F.	1%
4c	do. to 2-19-18	86°F.	29°F.	5%
4c	do. to 2-28-18	86°F.	29°F.	10%
1d	12-11-17 to 1-3-18	86°F.	29°F.	None
1d	do. to 1-18-18	86°F.	29°F.	do.
1d	do. to 1-31-18	86°F.	29°F.	do.
1d	do. to 2-6-18	86°F.	29°F.	do.
1d	do. to 2-19-18	86°F.	29°F.	do.
1d	do. to 2-28-18	86°F.	29°F.	do.

Table 7 - Continued

Series No.	Date of Exposure	Range of Temperature		Germination*
		Max.	Min.	
1d	12-11-17 to 2-28-18	86°F.	29°F.	None
4d	12-13-17 to 1-3-18	86°F.	29°F.	do.
4d	do. to 1-18-18	86°F.	29°F.	do.
4d	do. to 1-31-18	86°F.	29°F.	do.
4d	do. to 2-6-18	86°F.	29°F.	do.
4d	do. to 2-19-18	86°F.	29°F.	do.
4d	do. to 2-28-18	86°F.	29°F.	do.

* Two to four days at room temperature. Hanging drops of water in Van Tieghem cells.

These results indicate that unprotected urediniospores of P. coronifera Kleb., lose their viability within 22 days with a minimum temperature of -27°F.

When afforded protection these spores remain viable as long as 44 days.

Exposed to the light, viability is lost within 23 days, though the maximum temperature was 86°F. and the minimum 29°F.

Kept in the dark, spores at a similar temperature to those exposed to the light remained viable as long as 79 days.

Table 8.

Teliospore germination studies of Puccinia coronifera Kleb., from greenhouse seedlings

No.	Legend	Date	Source	Germination*
1.	O_3 Avena sterilis $_1O_7$	1-21-18	Avena sterilis Univ. Farm Minn.	3-2-18 to 3-19-18 None
2.	do.	do.	do.	3-28-18 to 4-8-18 None
3.	O_3 Avena sterilis $_1O_7$	2-19-18	do.	3-28-18 to 4-8-18 None
4.	O_3 Avena sterilis $_1O_6$	do.	do.	do.
5.	O_3 Avena sterilis $_1O_7$ Minn. 281	3-19-18	do.	do.
6.	O_3 Avena sterilis $_1O_8$	do.	do.	do.
7.	do.	do.	do.	
8.	O_3 Avena sterilis 1 Minn. 281 Alabama Appler 617	3-25-18	do.	3-28-18 to 4-8-18 None
9.	O_3 Avena sterilis$_1$ O_8 White Russian Cal.-Okla. Red Rust Proof	do.	do.	4-14-18 to 4-24-18 None
10.	O_3 Avena sterilis$_1$ O_8 Swedish Crown 526	4-2-18	do.	3-28-18 to 4-8-18
11.	O_3 Avena sterilis$_1$ O_8 Virginia Burt	4-7-18	do.	4-14-18 to 4-24-18 None
12.	O_3 Avena sterilis$_1$ O_8 Virginia Swedish Select	do.	do.	do.
13.	O_3 Avena sterilis$_1$ O_8 Victory 514	do.	do.	do.

Table 8 - Continued

No.	Legend	Date	Source	Germination*
14.	O_3 Avena sterilis$_1$ O_7 Minn. 381$_1$ Alabama Burt Spring strain	4-3-18	Avena sterilis Univ. Farm Minn.	4-14-18 to 4-21-18 None
15.	Avena sativa$_1$ O_{10} Silver Minn. 506	4-7-18	Avena sativa Univ. Farm Minn.	4-27-18 to 5-3-18 None
16.	O_3 Avena sterilis$_1$ O_8 Swedish Crown 526	4-20-18	Avena sterilis Univ. Farm Minn.	do.

* Hanging drops of water in Van Tieghem cells.

Negative results attendant on all attempts to germinate teliospores produced on oat seedlings in the greenhouse is but further evidence of the necessity of a period of rest and over-wintering previous to the probable viability of such spores.

GENERAL OBSERVATIONS

1. McAlpine (1906)[14] ventures the opinion that crown rust of oats was probably introduced into Australia by means of seed. He does not state whether he thought the rust was carried within or upon the seed in the form of mycelium or urediniospores.

As far as surface borne urediniospores are concerned it seems questionable whether under ordinary conditions urediniospores would remain viable upon the seed surface long enough to be transported any great distance and still be able, after long periods of time, to infect the developing seedlings.

In an attempt to throw some light upon this question the following experiment was devised.

Twenty oat seeds were moistened in water and heavily smeared with fresh urediniospores. Five seeds were then planted about one-half inch deep in each of four four-inch pots of a uniform soil mixture. These pots were placed in a ventilated glass cage in order to protect the developing seedlings from chance infection from air borne spores. See Figure 1, Plate III.

After the seedlings had been allowed to grow for ten days, a sufficient period to show evidence of infection, it was found that out of the twenty seedlings none of them became infected. The temperature within the cage was slightly higher than in the greenhouse and moisture was present in

sufficient amounts to cause guttation from the seedling leaves.

These results, though the experimental work was not extensive, would seem to indicate that in the case of P. coronifera Kleb., urediniospores borne upon the surface of the seed do not commonly offer a favorable means of spreading the rust to the seedling plants developed from these seeds.

2. In the field, the soil beneath cereals heavily rusted with P. graminis Pers., is often found literally covered with fallen urediniospores. The idea has been concieved that seedlings penetrating such soil might become infected and the rust aided in its spread in this way. Greenhouse experiments have proven this possible with P. graminis Pers.

In order to determine if such infection were possible in the case of P. coronifera Kleb., the following experiment was devised.

After soaking in water for twenty-four hours, six oat seeds were planted about one-half inch deep in each of four four-inch pots of a uniform soil mixture. The surface soil was then heavily dusted with fresh urediniospores. These pots were then placed in the glass cage illustrated in Fig. 1, Plate III, to avoid possible chance infection of the seedlings by air borne spores. Watering was avoided in order to prevent germination of the spores before the seedlings should come in contact with them. After ten days time none of the twenty-two seedlings that developed showed any signs of infection though guttation

occurred from the seedling leaves, affording optimum conditions for spore germination.

These results indicate at least that seedling infection caused by emergence through soil densely covered with viable urediniospores does not occur readily.

3. The possibility of urediniospore-producing mycelium overwintering in the host plant and producing a new crop of urediniospores in the spring, together with the overwintering of urediniospores in the field, was considered.

The urediniospore germination studies would seem to indicate that under Minnesota conditions urediniospores cannot withstand the extremely low temperatures of winter. In the field even before winter had set in all urediniospores had disappeared and only the teliospores were in evidence. Two pots of oat plants, heavily rusted with the leaf rust were allowed to remain outside during the winter. The plants of course were winter killed and when removed to the greenhouse in early April did not revive. The urediniospore producing mycelium if still alive, which one would naturally doubt, produced no new crop of spores.

From this more or less limited observational evidence, then, it seems improbable that under Minnesota conditions a perennial mycelium exists which is capable of producing a new crop of urediniospores the following spring after overwintering on the infected oat host, though Bolley and Pritchard (1899)[3] consider it in general quite possible, even though no experimental data is offered to substan-

tiate the opinion. It seems equally improbable that the urediniospores themselves can overwinter and cause infection the following spring. Just what possibility there is of the existence of a perennial mycelium or the overwintering of the urediniospores among the wild grasses, has not been determined.

4. Mains (1916),[13] working with P. coronata Cda., has shown that low temperatures, lack of moisture in the moist chamber and the absence of light retards the development of the leaf rust on oats.

These same observations have been made in the present work though only one definite experiment was performed and that to determine the effect of light upon the degree of infection and the rate of pustule formation.

Four pots of oats of the same seed lot and grown under the same conditions, were inoculated on the same date with inoculum from the same source. Two pots were placed in a pan of water and covered with a glass bell jar; the other two pots were given similar moisture and temperature conditions though covered by a glass-topped metal moist chamber from which light was excluded. See Figure 3, Plate III.

All four pots were removed from the moist chambers after forty-eight hours but retained for two days more under the light and dark covers. At the end of this period the plants in the dark had become spindly and nearly etiolated.

Flecks appeared on all the pots of seedlings at about the same time. Pustules ruptured within ten days upon the plants kept in the light and within twelve days upon those kept in the dark. Infection, one hundred percent, in each case, appeared normal on all the seedlings, though not so heavy on the plants grown in the dark. The plants that had been kept in the dark, after several days exposure to the light retained nearly normal growth though the effect of etiolation was evidenced by dead areas at the tips of the leaf blades.

Twenty-eight days after inoculation pigment appeared on one of the plants that had been exposed to the light while twenty-six days after inoculation a profuse production of teliospores was noted on every plant in one of the pots that had been kept in the dark. See Figure 1, Plate IV. The significance of pigment appearance and teliospore formation on inoculated seedlings will be discussed in the last two general observations recorded here.

5. It will be noted in the tables showing results of urediniospore inoculations on oats, that the notation of the appearance of a purple pigment surrounding infected areas of the leaves is not uncommon. The variety of the host plant, its age before inoculation, the length of time of infection, the history of the inoculum, its method of application and all other externally visible environmental factors seem to have no direct correlation with this phenomenon of pigment formation. Wheldale (1916)[32] regarding this

anthocyanin pigment formation in plants attacked by fungi, states, "It is frequently found that the pathological conditions called forth by the attacks of Fungi are accompanied by abnormal development of anthocyanin. In leaves of Tussilago, for instance, infected by Puccinia a circular band of anthocyanin often appears surrounding the aecidium spots.....Injury to the living tissues of the conducting system of the veins, midrib or petiole of the leaf, or of corresponding tissue in the stem, leads to an accumulation of synthetic products in the leaves..... .....It seems likely also that parasitic growths may interfere with the progress of the translocation current through the small veins of the leaf, thereby causing congested areas to arise in which the sugar contents are above normal. But it is conceivable that the pathological condition resultant on fungal attacks may be the direct cause, in some way, of pigment formation."

In view of this intrepretation and the relatively general occurrence of this anthocyanin pigmentation we feel justified in assuming that pigment formation as a phenomenon connected with the infection of oats by P. coronifera Kleb., is not a sign of resistance on the part of the host to the attacks of the rust parasite.

6. Parker (1918)[18] places some importance upon the early production of telia on oat seedlings. He says, "It is certain that in the hundreds of seedlings described as very susceptible in the present experiments telia were not produced

on a single one following a normal and abundant production of uredinia."

In the present investigations this was not the case. Although certain oat varieties showing resistance to attacks of the crown rust did produce telia, other very susceptible varieties also produced telia freely and in great abundance. Super-susceptibility on the part of the host may bring about the formation of telia due to conditions as explained by Wheldale quoted under observation 5, although resistant hosts may react in some way as to be unfavorable to continued urediniospore production on the part of the fungus, and thus hasten the completion of its life cycle and the early production of telia. For verification of this interpretation see Table 1, pp. 15-22.

Parker has used this phenomenon of teliospore production, in certain cases, as a basis for classification of resistant varieties. We believe such a basis for the classification of resistance unreliable.

He lists Ligowa oats as susceptible and yet we find Ligowa oats although heavily infected, producing pigment and telia both when growing under normal conditions and when subjected to adverse environmental circumstance. See Figure 1, Plate IV.

Avena sterilis he considers for the most part susceptible. We find it producing telia, pigment and extensive hypersensitive areas. Figure 1, Plate V, shows leaves of Avena sterilis infected by P. coronifera Kleb.

The "strain" of rust from St. Paul, Minnesota, indicated by "L" caused a very light infection, small, scattered uredinia, large hypersensitive areas and the early production of telia. The "strain" of rust from Tallulah, Alabama, indicated by "T" caused heavy, normal infection without any evidence of pigment or telia formation.

Swedish Select oats was considered susceptible and yet Swedish Select oats from Virginia produced telia in abundance in our experiments.

Appler oats was considered resistant. Figure 1, Plate VI, shows Appler oats from Alabama infected with P. coronifera Kleb. "T" indicates normal infection with the "strain" of rust from Tallulah, Alabama; "L" indicates a heavy production of telia and extensive dead areas by the St. Paul, Minnesota "strain."

Burt oats was considered susceptible. In our experiments Burt oats from Alabama showed a similar condition to that described for Appler.

Therefore, though the production of telia when associated with other phenomena indicating resistance may be additional evidence to justify the classification of oat varieties as resistant, certainly results obtained in the present work seem to show that this phenomenon of telia formation on oat seedlings is variable and largely dependent upon environmental factors and possibly the "strain" of rust employed, to such an extent at least as to make it a rather unreliable basis for the determination of true resistance.

SUMMARY

1. P. coronifera Kleb., on the basis of experimental evidence, is the correct scientific name for the crown rust of oats.

2. In Europe P. coronifera Kleb., is divided into at least nine biologic forms, one of which is avenae, the form on oats.

3. The crown rust on oats in the United States has a host range, particularly under greenhouse conditions, that is much more extensive than is credited in Europe.

4. There seems to be slight differences in infection capabilities between four "strains" of P. coronifera Kleb., used in this experiment though from the evidence at hand, no conclusions have been drawn.

5. There are a number of common hosts for P. coronifera Kleb. and P. graminis avenae Erikss. and Henn.

6. Aeciospores from dried specimens of Rhamnus were not viable after a period of six months from date of collection.

7. Urediniospores germinated at a temperature as low as 7°C. with an optimum of 18°C. and a maximum of 32°C.

8. Urediniospores from dried specimens of Avena sativa proved to be viable as long as 87 days after date of collection.

9. Unprotected, urediniospores lose their viability within 22 days with a minimum temperature of -27°F.

10. When afforded protection these spores remain viable as long as 44 days.

11. Exposed to light, viability of urediniospores is lost within 23 days with a maximum temperature of 86°F. and a minimum of 29°F.

12. Kept in the dark, urediniospores at a similar temperature to those exposed to the light, remain viable as long as 79 days.

13. Urediniospores borne on the surface of oats seed do not offer a ready means of infecting seedlings developed from these seeds.

14. Seedlings of oats emerging through soil heavily covered with viable urediniospores are not readily infected.

15. Under Minnesota conditions, a perennial mycelium capable of producing a new crop of urediniospores after overwintering, does not exist. What the situation is in the case of wild grasses has not been determined.

16. Urediniospores do not remain viable over winter on oats, nor does continued production take place. What the situation is in regard to wild grasses has not been determined.

17. Previous to overwintering and as late in the spring as May 3, teliospores are incapable of germination.

18. Teliospores developed on oat seedlings in the greenhouse and not afforded a period of overwintering did not germinate.

19. Environmental factors influenced the development of the rust on oats as well as the rate of pustule formation.

20. Etiolation brings about the early formation of telia on oat seedlings.

21. Anthocyanin pigment formation surrounding uredinia on infected oat leaves is a common phenomenon though not correlated with resistance or susceptibility.

22. The appearance of telia on seedling oat leaves is not a reliable basis for determining resistance of oat varieties.

-------0-------

LITERATURE CITED

1. Arthur, J.C. 1918 — In a letter dated Feb. 14, 1918.

2. Bary, Anton de 1866 — In Ber. Akad. Wiss., p.205, 1866. Cited By Sydow, P. and H. In Monograp. Ured. V. 1, p.699, 1904.

3. Bolley, H.L. and Pritchard, F.J. 1906 — Rust Problems. Facts, Observations and Theories. Possible Means of Control. N.Dak.Agr.Exp.Sta.Bul. 68, p.607-672.

4. Carleton, M.A. 1899 — Cereal Rusts of the United States. A Physiological Investigation. U.S.Dept. Agr.Div.Veg.Phys. and Path.Bul. 16, 74 p.

5. Christman, A.H. 1904 — Observations on the Wintering of Grain Rusts. Trans.Wis.Acad.Sci. V.15, pt.1, p. 98-109.

6. Corda, A.C.J. 1873 — Icones Fungorum. V.1, p.6. Cited by Sydow, P. and H. in Monograp. Ured. V.1, p.699, 1904.

7. Davis, J.J. 1914 — A Provisional List of the Parasitic Fungi of Wisconsin. Trans.Wis.Acad.Sci. V.XVII, pt. II, p. 904.

8. Eriksson, J. 1909 — Neue Studien über die Spezialisirung der grasbewohnenden Kronenrostarten. In Ark.Bot., Bd.8, No. 3, Hft.1-3 , 26p., 1 Taf., 5 Tab.

9. Grove, W.B. 1913 — The British Rust Fungi 412p. London

10. Johnson, E.C. 1912 — Cardinal Temperatures for the Germination of Uredospores of Cereal Rusts. Abst. in Phytopath. V.2, No. 1, p.47-8.

11. Klebahn, H. 1892 — In Zeitschr. fur Pflanzenkrankh. V.II, p.337 Cited by Sydow, P. and H. in Monograp. Ured. V.1, p.699, 1904.

12. Klebahn, H, 1904 — Die wirtwechselnden Rostpilze 447p. Berlin.

13. Mains, E.B. 1917 — The relation of some Rusts to the Physiology of their Hosts. In Amer. Jour.Bot. V.4, p.179-220.

14. McAlpine, D. 1906. — The Rusts of Australia 349p. Melbourne.

15. Mühlenthaler, F. 1911 — Infektionsversuche mit Rhamnus befallenden Kronenrosten. In Centbl.Bakt.Abt.2, Bd.30, No.16-18, p.386-419.

16. Nielsen, P. 1875 — In Ugeskrift for Landmaend. Bd.I, p.549. 1875. Cited by Sydow, P. and H. in Monograp. Ured. V.1, p.699, 1904.

17. Pammel, L.H. 1892 — Some Diseases of Plants common to Iowa Cereals. Ia.Agr.Exp.Sta.Bul. 18, p.505.

18. Parker, J.H. 1918 — Greenhouse Experiments on the Rust Resistance of Oat Varieties. U.S.D.A. Bul.629.

19. Reed, H.S. and Holmes, F.S. 1913 — A Study of Winter Resistance of the Uredospore of Puccinia coronata. In Va. Agr.Exp.Sta.Ann.Rpt. 1911-12, p. 18-81, fig.15.

20. Reed, G.M. and Hursch, C.R. and Brentzel, W.E. 1917 — A systematic and physiological Study of Rusts. Mo.Sta.Bul. 147, p.28.

21. Stakman, E.C. and Piemeisel, F.J. 1917 — Biologic Froms of Puccinia graminis on Cereals and Grasses. In Jour.Agr.Res. V.10, No.9, p.429-496.

22. Wheldale, M. 1916. — The Anthocyanin Pigments of Plants. p.83.

EXPLANATION OF PLATES

Plate I.

Figure 1. Implements used in the inoculation work with cereal and grass seedlings.

Figure 2. One of the moist chambers in which the inoculated grass and cereal seedlings were placed during the incubation period of the rust spores.

Plate II.

Figure 1. Pots of inoculated seedlings upon the greenhouse bench, showing one of the cages used to separate the various rust "strains" on the bench and to cover the inoculated and uninoculated seedlings when the ventilators were opened and a possibility of chance infection from wind blown spores existed.

Figure 2. Method of growing the seedlings previous to inoculation.

Plate III.

Figure 1. Glass cages used to protect seedlings from possible air borne infection with urediniospores.

These cages were used in the experiments with seeds smeared with urediniospores before planting as well as in the experiment to determine the possibility of seedling infection by emergence through soil heavily dusted with urediniospores.

Note ventilation openings at the base of the right hand cage. A similar set of openings is provided at the top of the opposite side of the cage.

Figure 2. Light and dark moist chambers used in the experiment to determine the effect of light on the degree of infection and the rate of pustule formation on inoculated oat plants.

Plate IV.

Figure 1. At "D" the teliospores formed on etiolated seedling oat leaves are shown; at "L" the normal production of urediniospores on the seedlings kept in the light.

Plate V.

Figure 1. *Avena sterilis* infected with *P. coronifera* Kleb. "L" shows the production of telia and the extensive dead areas by the St. Paul, Minn. "strain" of rust. "T" shows normal production of urediniospores by the Tallulah, Alabama "strain."

Plate VI.

Figure 1. Oats, Alabama-Appler 617 infected with *P. coronifera* Kleb.

At "T" normal production of urediniospores by the Tallulah, Alabama "strain" of rust is shown; at "L" the heavy production of telia surrounded by hypersensitive areas produced by the St. Paul, Minnesota "strain."

Plate VII.

Figure 1. Aecia of *P. coronifera* Kleb., on leaves of *Rhamnus*.

Figure 2. Photomicrograph of urediniospores of *P. coronifera* Kleb.

Plate I.

Figure 1.

Figure 2.

Plate II.

Figure 1.

Figure 2.

Plate III.

Figure 1.

Figure 2.

Plate IV.

Figure 1.

Figure 1.

Plate VI.

Figure 1.

Figure 1.

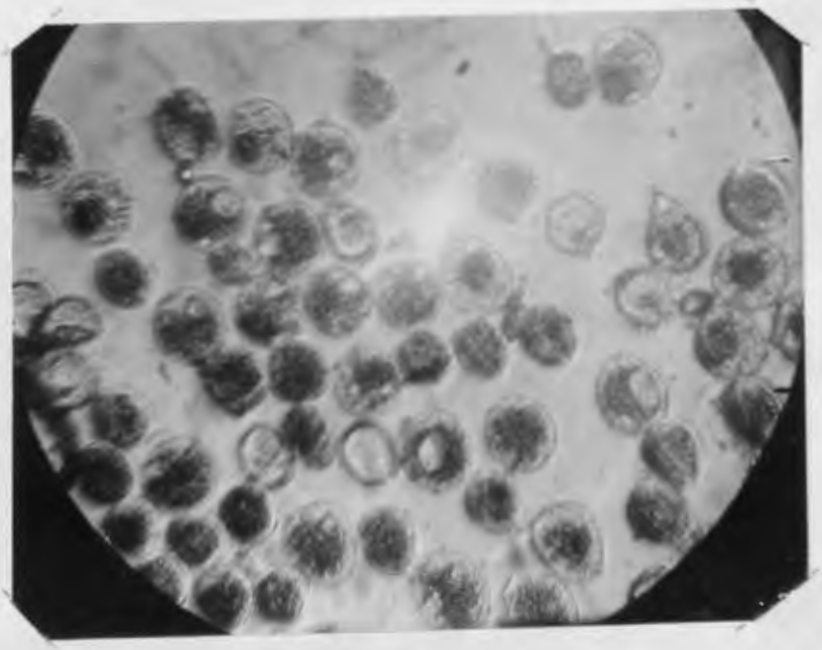

Figure 2.