UM Libraries Depository

103194907008

This Thesis Has Been

MICROFILMED

Negative No. T-

161

Form 26

VARIETAL RESISTANCE OF OATS
TO PUCCINIA CORONIFERA

by

William Edward Brentzel, B. S. in Agr.

SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in the

GRADUATE SCHOOL

of the

UNIVERSITY OF MISSOURI

Approved Feb. 5, 1917
George M. Reed.

1917

✓

378.7 M71

XB 753

VARIETAL RESISTANCE OF OATS
TO PUCCINIA CORONIFERA

INTRODUCTION

Oats grow best in a cool, rather moist climate, and are most largely produced in the North Temperate Zone. Among the leading countries in the production of this crop are the United States, European Russia, Germany, France, Canada, Austria-Hungary, and the United Kingdom. According to the Bureau of Statistics of the United States Department of Agriculture the world's production of oats is about four billion bushels annually, or about the same as that of corn or wheat. In the five year period from 1906 to 1910 the average annual production of oats in the United States was 932 million bushels or a little less than one-fourth of the world's production. European Russia averaged 865 million bushels in the same period, Germany 583 million bushels, France 299 million bushels, and Canada 295 million bushels.

The ten leading states in the production of oats are, in order of bushels produced, Iowa, Illinois, Wisconsin, Minnesota, Nebraska, Ohio, Indiana, New York, Michigan, and North Dakota. The first five states named produce more than half of the crop of

the entire country, while the first four, comprising the central portion of the upper Mississippi Valley, produce more than 400 million bushels or about one-tenth of the entire production of the world. More than ten per cent. of the total land area of Iowa and Illinois and about seven per cent. of the entire acreage of improved land in the United States are annually devoted to the production of oats. In Missouri oats are ranked third in value as a cereal crop.

Among field crops in the United States oats rank fifth in value, falling below corn, cotton, hay, and wheat. The average area devoted annually to the production of oats in the United States for the ten year period from 1902 to 1911 was 31,779,000 acres; the average total production 926,202,000 bushels, and the average farm value \$337,840,000.

DISEASES OF OATS

The most common and destructive diseases of oats are smuts and rusts. The loose smuts, Ustilago avenae and U. levis, are found wherever oats are cultivated. Besides occurring upon the cultivated oats they are found upon Avena fatua and various other forms.

Infection of oats by smuts takes place by means of the germinating conidia at the time of germination

of the seed grain. The fungus matures about the time the oat plant is in flower. With Ustilago avenae the whole ovule with its inclosing glumes are largely converted into a mass of sooty spores. In the case of Ustilago levis the mycelium destroys the kernels and the glumes only partially. Johnson (13), in 1916, estimated the average annual loss to the oat crop in the United States caused by smuts to be about four per cent. of the total crop.

Either of the two smuts may be controlled by treating the seed grain in a solution of formalin or in hot water. The formalin method consists in dipping the seed in a solution containing one pint of formalin to thirty gallons of water for a few minutes and then allowing the seed to remain wet in the sacks for about two hours before spreading to dry.

The common rusts of oats are crown rust, Puccinia coronifera (the name, P. coronifera, superseded the old name, P. coronata and was used by Eriksson after having been established by Klebahn) and stem rust, Puccinia graminis. They have a well developed septate mycelium which sends to the surface of the host numerous sporophores each bearing a single spore, the uredospore or summer spore. Groups of these spores on the surface of the plant form reddish spots giving rise to the name rust.

Crown Rust.--The uredospores of crown rust appear on the leaves and stems of the plants in numerous small somewhat elongated pustules. They are ovate with roughened surfaces and orange-yellow color. They measure 20-24 x 28-32 microns. These spores fall upon the surfaces of the uninfected leaves, stems, and plants where they germinate and send out germ-tubes that penetrate the host and form new mycelia. By this means the rust spreads rapidly over the growing oats.

Later in the season as the oat plants mature teleutospores or winter spores are produced. These do not rupture the epidermis of the host but because of their yellowish-brown to brown color they are visible through the epidermis. The teleutospores of crown rust are generally two-celled, though unicellular are sometimes found. They have thick walls and a short pedicel. In form they are notably distinctive in being cuneate with several horn-like projections on the thickened apex forming a crown-like structure; hence, the name 'crown rust.' They measure 12-20 x 35-60 microns.

The teleutospores will not germinate until after having rested through the winter or at least through a part of it. When germination occurs in the spring a short thread is developed and from this a number of minute spores, sporidia, are cut off (generally four

of them) which are scattered by the spring winds.

Puccinia coronifera is a heteroecious rust. The sporidia will not infect the oat plant. They infect the buckthorn bushes, species of Rhamnus. The germ-tubes from the sporidia grow into the tissue of the host and make a yellowish and often swollen spot. In some 15 to 20 days aecidiospores break through the lower epidermis of the leaf, forming chains of spores which arise at the bottom of a cup-shaped depression, the cluster cup or aecidium cup. The aecidiospores measure 14-19 x 18-25 microns. They germinate upon the oat plant and other grasses where the mycelium for the uredo stage is developed.

One section of crown rust has Rhamnus cathartica (R. lanceolata Pursh. in America) for its aecidial host with uredospores on oats and other grasses, and another section has Rhamnus frangularia (R. carolinana Walt. in America) for its aecidial host but the uredospores do not occur on oats. The former section is called Puccinia coronifera (previously P. lolii by Nielsen) and the latter by the old name, Puccinia coronata.

The Stem Rust.--The stem rust on oats is less common than the crown rust though both are often found on the same plant. The uredospores are ovate with rather thick walls measuring 10-15 x 20-35 microns.

They have numerous echinulations of small spine-like appendages.

The teleutospores are generally disposed in a linear manner on the stems, leaves, and floral parts of the host. They arise in the early part of the season in the uredo sorus. Later in the season many teleutospores are developed giving rise to the black rust at harvest time. They are broad at the apex and have a persistent pedicel. They measure 12-22 x 35-60 microns and are deep brown in color.

Puccinia graminis is also heteroecious. The sporidia infect the barberry bushes, species of Berberis, the most common of which is Berberis vulgaris. Later aecidiospores more or less spherical in form that measure 14 to 26 microns are developed on this host.

Damages of Oat Rusts.--The rust mycelium traverses the tissue of the host. Bolley and Pritchard (2) state that in a wheat plant which fails to fill grain because of rust there is hardly a single cell that is not many times perforated by the branching fungus threads. The action of the fungus causes a disorganization of the chlorophyll and protoplasm of the host. Where there is much leaf rust the leaves are almost completely deprived of chlorophyll leaving the stems to elaborate food material for the plant. Further, the leaf rust is not confined to the leaves entirely but occurs to some extent on the stems and is almost always

accompanied by the stem rust, especially in the latter part of the season. Not only are the plant materials disorganized but also the epidermis of the plant is ruptured to such an extent that evaporation of moisture is materially increased. The result is that the plant may fail completely to fill grain and where grain is produced it is more or less shriveled and light in weight.

In the Gulf Coast States excepting northern Texas, and South Carolina oat rust almost prohibits the growing of spring oats. Epidemics frequently occur northward in Wisconsin and beyond the Canadian line and east of the dry belt of the Great Plains region of the United States. Oat rusts are found in Europe, Russia, and South Africa. And according to McAlpine the crown rust of oats is common in Australia, having been introduced about 1896.

It is difficult to estimate the damage done by either crown or stem rust of oats. Bolley (2) stated in 1906 that it seems quite within a reasonable guess that the average annual loss to the wheat crop of the United States alone approximates 15 to 20 millions of dollars due to wheat rust. Freeman and Johnson (9), in 1911, stated that the stem rust of oats, if not more harmful, is fully as destructive as the stem rust of wheat. The crown rust of oats, which is probably

the most destructive of the leaf rust group, and the stem rust of oats are usually commingled. It is, therefore, difficult to estimate how much of the resulting damage is due to each.

PHYSIOLOGICAL RACES

Host Plants.--Sydow (19) reports the following as hosts for crown rust of oats:

Puccinia coronifera.

Aecidial stage.

Rhamnus cathartica L., European host.

Rhamnus lanceolata Pursh., American host.

Uredo and teleuto stage

Avena sativa L.

" fatua L.

Lolium perenne L.

Festuca elatior L.

Holcus mollis L.

" lanatus L.

Alopecurus pratensis L.

" nigricans

Glyceria aquatica Wahl.

In addition to these the writer produced infection on Avena brevis, A. chinensis, A. ludoviciana, A. elegantissima, A. orientalis, A. sterilis, and A. strigosa.

The rusts produced on different species of grasses, though having the same aecidial host, do not interchange freely to other species of grasses. The following table taken from Eriksson's article (5) shows somewhat in detail how the different forms of rust succeed on hosts others than their own.

Puccinia coronifera Kleb.

Aecidium catharticae

Uredospores from	<i>Avena</i> <i>Sativa</i>	<i>Alopecurus</i> <i>pratensis</i>	<i>Festuca</i> <i>elator</i>	<i>Glyceria</i> <i>aquatica</i>	<i>Holcus</i> <i>lanatus</i>	<i>Lolium</i> <i>perenne</i>
<i>Avena</i> A. <i>sativa</i>	+	-	-		-	-
<i>Alopecuri</i> A. <i>pratensis</i>	rarely	+	-			
<i>Festuca</i> F. <i>elator</i>	-	-	+	-		-
<i>Glyceria</i> G. <i>aquatica</i>		-	-	+		
<i>Holci</i> H. <i>lanatus</i>	-				+	
<i>Lolii</i> L. <i>perenne</i>	-		rarely	-	-	+

Where infection occurred it is indicated by +.

No infection is indicated by -

Each form is almost exclusively confined to its particular host and is not able to infect other species. Thus, crown rust from a host, *Avena sativa*, can propagate rust on *Avena sativa* but not on *Lolium perenne*, *Festuca elator*, etc.

Eriksson's work shows Puccinia coronifera to be divided into six of these special forms or physiological races, each very similar to the other in morphological appearance though different with regard to their physiological reaction.

Puccinia graminis has a much greater number of host species than Puccinia coronifera. Sydow (9) reports 176. The rust produced on these species is not restricted so definitely to a single host as in the case of Puccinia coronifera. The following taken from Eriksson's data (6) shows some of the hosts of the three principal physiological races of Puccinia graminis.

Puccinia graminis on wheat, sparingly on barley and rye.

Puccinia graminis on oats, various species of Avena, Dactylis glomerata L., Alopecurus pratensis L., Milium effusum, Lamarckia aurea Mch., Bromus arvensis L., Trisetum distichophyllum Beauv., Bromus brachystachys Horn., Bromus madritensis L., Koeleria setacea DC., Festuca myurus Ehrh., Festuca tenuiflora Sibth., Festuca sciroides Roth., Phalaris canariensis L., Phleum asperum Vill., and Briza maxima L.

Puccinia graminis on rye, barley, Hordeum jubatum L., Hordeum comosum J. and Presl., Bromus secalinus L., Elmus arenarius L., Agropyron repens Beauv., Agropyron caninum R. and Sch., and Agropyron desertorum Fisch.

Other physiological races which are more or less well established are as follows: Puccinia graminis agrostis Eriks. infecting Agrostis canina, Agrostis stolonifera; Puccinia graminis airae Eriks. infecting Airae; and Puccinia graminis poae Eriks. and Henn. infecting Poa compressa.

Physiological differences have been observed in leaf rusts of wheat and rye, Puccinia rubigo-vera. The leaf rust of wheat is not distinguished from that of rye by morphological characteristics, yet the leaf rust of rye cannot ordinarily be transferred to wheat.

The results of infection experiments of investigators in different geographic areas vary when working with apparently the same physiological race. For, example, Eriksson in Sweden reports a special race of Puccinia graminis on barley and rye, a special race on wheat, and another special race on oats while Carleton in the United States reports a special race on barley and wheat, a special race on rye, and another on oats. In other words, the race on barley or wheat goes to barley or wheat with ease in this country while in Sweden the race on barley goes with difficulty to wheat and the race on wheat with difficulty to barley. In this connection it may be concluded as McAlpine (15), Stakman (18), and Freeman and Johnson (9) concluded, that the same race of rust may consist of a number of

strains or varieties which behave differently in different geographic areas.

All forms of Puccinia coronifera are alike in that they are able to alternate on Rhamnus cathartica, producing aecidiospores thereon. The query presents itself whether this bush is not able to serve as a connecting bridge between the forms which show their distinguishing features in the uredo stage and whether there is a possibility of breaking down a physiological race by means of introducing the aecidial generation.

Eriksson (4), in 1898, remarked that many trials have conclusively proved that this does not happen with the black rust and its aecidial host, the barberry. Aecidiospores from black rust on oats are able to infect, among cereals, only oats, and aecidiospores from black rust of rye can produce infection only on rye, and so on. Eriksson's results lead to the conclusion that the degree of propagation of a rust is not at all affected by the intervention of the aecidial host, and that the aecidial host introduced will not break down the limit of a physiological race.

The Adaptation of Fungus to Uncongenial Hosts:--
There seems to be but little immediate ability on the part of the narrowly specialized rusts to adapt themselves to uncongenial hosts. This is shown by the fact that the number of hosts for a given rust are few. However, Freeman and Johnson (9) working with Puccinia graminis on wheat and barley found a measurable

difference in the size of the uredospores. Those on barley being considerably shorter and slightly narrower than those on wheat. But the wheat rust on barley lost in size while the barley rust on wheat gained in size, each changing in size to almost exactly that of the original or natural rust of the host.

Stakman (18) states that the conclusion is justified that by confining Puccinia graminis to Einkorn (Triticum monococcum L.), an uncongenial host, for successive generations through a year or more the rust adapts itself somewhat to its new host; but that it would require a very long period of time to fix the character to such a degree as to make a new physiological race.

The relation of Host to Fungus.---It is noticeable that in general the best developed rust is found on the most flourishing and vigorous plants. There seems to be a close symbiotic relation between the host and parasite. The closer the relation the less struggle there will be and slower and less noticeable will be the injurious effects.

Ward (2) remarks that a Uredine when flourishing in a leaf does not act as a devastating parasite, but on the other hand slowly taxes its host, and even stimulates the cells for some time to greater activity. This is often shown by the persistent green color and activity of the cells immediately around a pustule at a time when the rest of the leaf is yellow and faded.

It is believed that the relation of a given fungus to a particular host is specific. Vavilov (13) likens it to a chemical relation. Fungi, narrowly specialized ones in particular, may be used in some cases as a physiological test (or strictly speaking, reagent) for the recognition of the species in systematic and genetic studies of plants.

The Nature of Resistance.--Some plants escape rust, without exercising any power of resistance, by maturing early. Others have the power of overcoming or enduring a rust attack to a certain degree. Freeman (8) states that all the Fife and Blue Stem wheats can endure light or even moderate attacks but all go down quite uniformly under uniform conditions in a heavy epidemic.

Ward (21) has shown instances where the tissue of the host turns brown and dies, the destructive action of the infection tubes having killed the cells too rapidly. Since the dead cells are not suitable as a medium for further growth of the mycelium, the parasite dies. In such cases the non-adaptation of the parasite to the host is shown, not by any active resistance of the latter but by the fact that the parasite was too rapid in its onslaught. In such cases the plant is able to endure the rust attack

In other cases the germ-tube may enter the tissue of the host very readily but never form any haustoria and consequently no spores, though the presence of the mycelium may be betrayed by flecking of the leaves.

In this case it is thought that the haustoria die when they come in contact with the cell contents. A plant bearing such a relation to a fungus would have perfect resistance.

In regard to the relation of chemotaxis or morphological characteristics to infection Stakman (18), in 1914, stated that chemotaxis or its absence would hardly explain infection since the fungus succeeds in effecting an entrance even into the most immune forms. The evidence would rather seem to favor the view that the problem is one of toxins.

Ward (21) made infection curves with about ten species of Bromus and the brown rust based on the number of hairs, length of hairs, number and size of stomata, etc. He concluded that there is no resemblance between the infection curves and curves of structural factors of the leaf.

It seems to be pretty generally believed that the real resistance offered to the invasion of a rust mycelium is found in the protoplasm of the host.

Miss Marryat (14) in her notes on wheats immune to rust concluded that we are forced to fall back upon the theory that immunity to disease is due to the production of certain toxins and antitoxins produced by the host or parasite or both.

Freeman (8), in 1911, concluded that the possible role of enzymes of the protoplasm of host- cells in

relation to the fungus is suggestive.

OAT RUST CONTROL

Wintering of the Uredospores.---Carleton (3) was of the opinion that crown rust passed the winter in the uredo stage in the warmer latitudes of the United States. He found a case where volunteer oats bore this rust in both the uredo and teleuto stages in the first week of March at Washington, D. C. The uredospores were found to be apparently in good condition on leaves not yet dead. He also observed uredospores of both crown and stem rusts on oats in Kansas up to November 2.

Bolley (1) states that uredospores of Puccinia rubigo-vera and Puccinia coronata are developed to a greater or less extent during all months of the year in states south of Tennessee. In states north of this line there seems to be isolated cases in which the mycelium may persist depending, apparently, chiefly upon the point whether the attacked portion of the host persists or not.

McAlpine (15), after making observations on the wintering of rusts in Australia, states that when the winter is mild and green vegetation flourishes the mycelium of the rust fungus may continue to grow and may even produce spores; whereas, if the winter is severe and the mycelium does not remain in the perennial

part of the plant, then the continuance of the fungus is likely to be by teleutospores, which can last through the winter on dead stems or on other decaying vegetable matter. The so-called wintering of the uredo spores depends so much on the climate that in a mild climate the fungus may perpetuate itself exclusively by uredospores; whereas, under severe conditions it has to resort to teleutospores.

Hitchcock and Carleton (11) remarked that there seems to be good evidence that the mycelium of Puccinia rubigo-vera is able to pass the winter in the tissue of the wheat plant.

Bolley and Pritchard (2) stated, in 1906, that the wheat rust may pass through the winter by means of living rust filaments which persist in green leaves and other green parts of the wheat plant and other grass hosts which may chance to live through the winter. They thought it quite possible for the crown rust to pass the winter in this manner also.

In many places of the South the great problem of rusts is not how to survive the winter but how to pass through the extreme hot months of July, August, and September.

Dissemination of Spores.--Klebahn experimented with cotton plates in trees in different parts of Germany in the spring and summer seasons. After being exposed for a certain period of time the plates were taken

and washed out carefully. An examination of the wash water showed several thousand uredospores of Puccinia graminis and other rusts from each plate.

Freeman and Johnson (9) state that spores rise into the air where they may be carried hundred of miles a day in the direction of the air currents. In this way innumerable rust spores may be carried from regions where they are plentiful, either by the presence of the aecidial host or the wintering uredospores, to regions where grain is in a receptive condition. This interchange of spores between localities may take place mainly from south to north in early spring and summer, and from north to south in late summer and fall.

According to the theories of various workers, rust may be present to attack the oat crop, first, by wintering in the uredo stage near the growing oats; second, by wintering of the teleuto stage; third, by mycelium living through the winter in green plant tissue in a dormant condition developing uredospores in the spring when conditions are favorable; and fourth, by spores blowing in from other regions where conditions are favorable for spore production.

However, in seeking to explain the infection of spring grain as due to uredospores from neighboring grasses it should be remembered that artificial

inoculations give results which show a very definite restriction of different physiological races to certain hosts.

The Effect of Climate.---The question of the effect of climate on the prevalence of rust is a mooted question. Hitchcock and Carleton (11) remark that the most favorable conditions are warm wet weather, such as are generally afforded by frequent showers, hot sun and moist east winds.

Freeman and Johnson (9) think that sudden showers wash off many of the spores before germination occurs. However, fairly humid conditions and moderate temperatures are thought to be not only favorable but almost absolutely necessary for infection. They conclude from their investigations that a great amount of rain and high relative humidity do not in themselves go for a rust epidemic since both were higher in 1905 than in 1904 when there was a rust epidemic. But since the temperature in 1904 was 3.5 degrees subnormal they concluded that temperature is an important, it not the determining, factor for the rust epidemic of that year.

Johnson's work (12) shows the optimum temperature for germination of uredospores of crown rust to be from 12 to 17 degrees Centigrade and the maximum 31 degrees. If Johnson's results hold under field conditions a temperature of 12 to 17 degrees Centigrade

would be the optimum temperature for infection.

But a temperature above 31 degrees Centigrade would be prohibitive to rust infection. However, if the infection is well under way and some mycelia developed, a temperature of 31 degrees would not hinder but on the other hand would be favorable for development of rust mycelia.

It is pretty generally concluded that in general factors favoring rust development are factors favoring host development. Stakman (18) remarks that conditions normal for host plant are probably also the conditions under which the rusts develop best.

Effect of Soil Treatment.--In some instances it has been reported that certain chemicals added to the soil tend to immunize against disease. For instance, copper sulfate for the potato disease caused by Phytophthora infestans or Sach's solution with a small amount of copper sulfate, 5 to 10,000 parts, for the lettuce disease caused by Bremia lactucae. However, attempts by Marchal and also by Galloway to immunize cereals to rust were unsuccessful.

It is believed that chemicals have no direct effect upon the fungus but the effects are rather indirect, acting through the plant and affecting it first.

The principle that conditions favoring a normal

development of the host are also conducive to vigorous development of the rust may be remembered when trying to control rust by the use of chemicals.

Seed Treatment and Spraying.--McAlpine (15) states that since inoculation and infection take place when the oat plant is above the ground it is evident that treating the seed grain to prevent rust would be of little value. The treatment would, however, destroy spores already present on the surface and entangled in the 'brush' of the seed but inside the seed no mycelium has been traced.

Spraying experiments have been tried from time to time by various investigators, but for the most part without satisfactory results. Freeman and Johnson (9) conclude that there is doubt that spraying will ever be of practical value for rust prevention.

Rust Escaping Varieties.--since the conditions most favorable for rust development usually do not occur till just before the harvest season some varieties may ripen early enough to escape the rust.

Bolley and Pritchard (2) speak of the advantage of having the grain crop to mature as early as possible in order to be free from rust attacks.

Freeman and Johnson (9) have found by inoculations at various stages of development under field conditions that wheat inoculated from the time when the heads emerge until they are in full bloom rusted far more than plants

inoculated either before or after this stage of development. It is suggested that this fact might be due to a physiological weakness of the plant resulting from rapid growth and abundant elaboration of starch at this period. But since these experiments were carried out under field conditions, there is no proof that this critical period for wheat infection is not due to climatic conditions. Whatever may be the cause, if for any reason this period is delayed or lengthened the danger of an epidemic is imminent.

But to try to escape rust by early sowing or by growing early maturing varieties is not a sure means of avoiding rust damages. If the severity of infection is due to climatic conditions one is at the mercy of the weather. On the other hand, if severity of infection is due to a physiological weakness from rapid growth and abundant elaboration of plant food during the critical period, a period of about ten days, as suggested by Freeman and Johnson, it is certain that if uredospores are present during this period there is danger of an epidemic.

The only hopeful remedy is that of growing oats which will be able to resist the rust successfully when the weather and other conditions favor its development. But combined with this character of resistance must be all the other characters which make for the usefulness of the crop.

EXPERIMENTS WITH PUCCINIA CORONIFERA ON
DIFFERENT VARIETIES OF OATS IN THE GREENHOUSE

Production of Uredospores.--To test the different varieties of oats for their relative rust resisting power it was found necessary to have an abundance of rust spores ready at the time when the different varieties of oats were ready for inoculation. The stock of spores at hand to start with was small and several factors were met with in increasing the stock. Conditions of temperature and moisture seem to influence rust development. Johnson (14) showed the optimum temperature of crown rust uredospores to be from 12 to 17 degrees, the minimum 7 to 8 degrees, and the maximum 31 degrees. These low cardinal temperatures help to explain the difficulty with which infection takes place in a warm greenhouse on hot summer days. They also show how subnormal temperatures during the critical infection period of the host favor the spreading of rust.

It was needed to know how long a culture of rust would last under greenhouse conditions. Melhus (16) found that a culture would run three or four weeks before the extent of infection of host materially decreased. By giving the cultures a vigorous shaking about once every seven days in such a manner as to dislodge the spores, allowing them to settle upon uninfected parts, it was found that the culture could be

continued as long as any parts of the host were green.

To find out if spores produced through the age of the culture are equally viable two experiments were carried out. A culture was started and kept under a bell jar. When pustules appeared uredospores were collected. The first collection was made three days after the first appearance of rust by dusting or shaking the culture over glazed paper. Other collections were made each day extending over a period of nine days and a final collection was made when the culture was twenty-five days old. The spores were suspended in dextrose potato decoction in Van Tiegham cells for germination. The results of this experiment are as follows:

Age of Culture	Spores Counted	Spores Germinating	% Germ.	Temperature	Hours in Decoction
3 days	50	40	80	21-22	24.5
4 "	50	31	62	22-23	24.0
5 "	100	97	97	20+24	24.0
6 "	100	91	91	24-25	26.5
7 "	100	67	67	24-26	23.5
8 "	100	17	17	23-22	25.5
9 "	100	84	84	23-23	24.5
10 "	100	66	66	23-21	24.0
11 "	100	41	41	29-19	23.5
--					
25 "	100	92	92	22-21	24.5

Though the table shows considerable variation in the per centage of spores germinating, yet it seems

that the spores collected when the culture was 11 or 25 days old were as viable as those collected when the culture was from three to five days old.

The second experiment was essentially the same as the first except that the test was one of infecting power rather than germination. The results are as follows:

Date Inoculated	Age of Plant	Age of Rust Culture	Date of 1st pust.	Incub. Period	No. plants inf.	Degree of Inf.
Mar. 10	21 da.	--	Mar. 18	8 days	5 plants,	med.
" 11	" "	1 day	" 21	10 "	6 "	light
" 12	" "	2 "	" 21	9 "	4 "	"
" 13	" "	3 "	" 22	9 "	6 "	med.
" 14	" "	4 "	" 28	14 "	2 "	light
" 15	" "	5 "	" 28	13 "	5 "	"
" 16	" "	6 "	" 29	13 "	5 "	med.
" 17	" "	7 "	" 29	12 "	7 "	"
" 18	" "	8 "	" 26	8 "	10 "	"
" 19	" "	9 "	" 28	9 "	9 "	"
" 20	" "	10 days	April 1	11 "	9 "	"
" 21	" "	11 "	" 2	11 "	3 "	light
" 22	" "	12 "	" 4	12 "	2 "	"
" 23	" "	13 "	" 4	11 "	1 "	"
" 24	" "	24 "	" 2	8 "	10 "	med.
" 25	" "	25 "	" 3	8 "	3 "	"
April 27	68 "	47 "	May 8	11 "	10 "	"

At the age of 15 days practically all the spores had disappeared from the rust culture. The culture was

reestablished by inoculation from its own spores and when the rust had developed sufficiently it was again used.

All plants inoculated were 21 days old at the time of inoculation; except the last lot, inoculated April 27, which was 68 days old. Ten plants, all in one pot, were used for each day's test.

The results show variation in degree of infection but the variation is not in agreement with the variation in age of the culture. As in the germination tests it would seem that the age of the culture, within certain limits at least, does not influence the infecting ability of the spores produced.

Other factors which were considered are, the effect of age of uredospores upon infection, the effect of age of host plant upon infection, the effect of continuously propagating from the same stock upon infection, and the effect of darkness upon infection. As to the first factor, the effect of age of uredospores, some mature spores were collected and kept in a glass-stoppered weighing bottle. The collection was made March 11 and when the spores were 97 days old, June 16, about 300 were suspended in water in Van Tieghem cells to test their power of germination. It was found that none of the spores germinated. When the spores were 104 days old susceptible oat plants were heavily inoculated with them. After incubating for 20 days only one pustule appeared

and it was very small. The spores do not retain their vitality long when stored.

Plants of various ages, from the age of those just coming through the soil to the age of 68 days, when the plants were 18 to 20 inches high and had five leaves, were infected. However, the larger plants seem to offer more resistance to spore formation. The pustules produced were smaller and required a longer incubation period.

Fromme (10) propagated rust in the greenhouse through 37 generations and found no decrease in degree of infection from such continuous cultures. He also found that the development of rust fungus is delayed by darkness. For example, upon keeping an inoculated plant in a dark box three days the incubation period was delayed three days. This explains in a measure why dark cloudy weather delays the incubation period. Fromme thought that rust development is dependent upon the transition products of photosynthesis, which is the basis for an explanation of the obligate parasitism of the rusts.

Relative humidity after the first 24 hours from inoculation does not modify the incubation period. It seems that a high moisture content is essential for spore germination but not essential for rust development after the plant is once infected. Temperature, however, favors rust development after infection.

Having some knowledge of how to cultivate the uredospores it was undertaken to prepare 20 to 30 six-inch pots of culture material each week for inoculation purposes.

Pots were planted with silvermine oats which was found to be very susceptible to infection by Puccinia coronifera. After the pots had been held under the proper conditions for 21 days the oats grew to a height of some six inches. They were then inoculated by dusting spores onto them from an old culture and placed under bell jars for incubation. The bell jars kept moisture about the plants to germinate the spores and protected the plants from the spores of other fungi, principally Erysiphe graminis, which were growing in the greenhouse. If, in spite of such care Erysiphe graminis got a start, it was controlled by dusting the plant with flowers of sulphur.

Variety Tests.--Plants of a convenient number of varieties, about 15 or 20, were started each week in two-inch pots. At the age of two weeks they were inoculated by dusting spores onto them from the stock cultures. Before inoculation the plants were thinned out so as to leave but ten to each pot. Two pots of each variety and one of the silvermine oats were prepared for each test. One pot containing a variety and one pot of silvermine oats were inoculated and the other pot containing a variety was used as a control. To make the inoculations

uniform all of the 15 or 20 pots containing different varieties and a pot for each variety containing silvermine oats were placed side by side and spores dusted onto all at the same time and from the same culture. The inoculated plants with the control plants were then placed under bell jars, a pot of one variety with its control lot and a pot of silvermine to each jar. The silvermine oats were used as a basis for comparison of the relative degrees of infection. Each variety was tested in this manner three or more times.

The results of the tests are given in the following table:

Experiments in the Greenhouse

RESULTS OF INOCULATIONS OF VARIOUS VARIETIES OF OATS AND RELATED SPECIES WITH PUCCINIA CORONIFERA

Variety	Seed No.	Date of Inoc.	Incubation Period	No. of Plants Infect.	Degree of Infect.
Avena brevis Roth.	1h	3/14	--	10-10*	xx **
" " "	1h	3/21	9 days	3-10	x
" " "	1h	3/28	11 "	6-10	x
" " "	1i	4/25	9 "	10-10	xx
" " "	1i	5/2	9 "	10-10	xx
" " "	1i	5/9	9 "	10-10	xx
" " "	1j	5/16	9 "	10-10	x
" " "	1j	5/23	9 "	10-10	xx
" " "	1j	5/30	9 "	8-9	x

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
<i>Avena brevis</i> Roth.	1k	5/16	9 days	10-10*	x**
" " "	1k	5/23	9 "	10-10	xx
" " "	1k	5/30	--	0-10	--
" " "	77a	5/16	9 "	10-10	xx
" " "	77a	5/23	9 "	10-10	xx
" " "	77a	5/30	9 "	10-10	xx
<i>Av. chinensis</i> Tisch. ¹	30b	4/25	9 "	10-10	xx
" " "	30b	5/2	9 "	10-10	xx
" " "	30b	5/9	9 "	10-10	xx
" " "	30c	5/16	9 "	10-10	xx
" " "	30c	5/23	9 "	10-10	xx
" " "	30c	5/30	--	0-10	--
<i>Av. fatua</i> L. <i>glabrata</i>	78a	5/16	9 "	5- 5	xx
"	78a	5/23	9 "	3-3	xx
"	78a	5/30	9 "	3-3	xx
"	79	4/25	9 "	4-4	xx
"	79	5/2	9 "	4-4	xx
"	79	5/9	9 "	10-10	xx
"	79a	5/16	9 "	5-5	xx
"	79a	5/23	9 "	6-6	xx
"	79a	No germination.			

1. Probably the same as *Avena nuda* L.

Variety	Seed No.	Date of Inoc.	Incubation Period	No. of Plants Infect.	Degree of Infect.
Av. ludoviciana Dur. ¹	80	4/25	9 days	10-10*	xx**
" " "	80	5/2	9 "	10-10	xx
" " "	80	5/9	9 "	10-10	xx
" " "	80c	5/16	9 "	10-10	xx
" " "	80c	5/23	9 "	10-10	xx
" " "	80c	5/30	9 "	10-10	xx
Av. nuda L.	25a	4/4	9 "	10-10	xx _x
Av. nuda L. elegantissima	26b	5/16	9 "	10-10	xx
"	26b	5/23	9 "	10-10	xx
"	26b	5/30	9 "	10-10	xx
Av. orientalis Schreb. obtusata Alef.	4b	3/14	8 "	10-10	xx
" "	4b	3/21	9 "	3-10	xx
" "	4b	3/28	9 "	6-6	xx
" "	33b	4/4	10 "	9-9	xx
" "	33b	4/11	9 "	10-10	xx
" "	33b	4/18	9 "	10-10	xx
" "	33c	5/16	9 "	10-10	xx
" "	33c	5/23	9 "	10-10	x
" "	33c	5/30	9 "	5-10	xx
" "	33d	5/16	9 "	10-10	xx
" "	33d	5/23	9 "	10-10	xx
" "	33d	5/30	9 "	10-10	xx

1. Probably the same as *Avena sterilis* L.

Variety	Seed No.	Date of Inoc.	Incubation Period	No. of Plants Infected	Degree of Infect.
<i>flava</i> Kcke.	31b	5/16	9 Days	10-10*	x**
" "	31b	5/23	9 "	10-10	xx
" "	31b	5/30	9 "	10-10	xx
<i>mutica</i> "	32c	5/16	9 "	10-10	xx
" "	32c	5/23	9 "	10-10	xx
" "	32c	5/30	9 "	5-10	xx
<i>pugnax</i> Alef.	65b	4/4	10 "	3-3	xx
<i>Av. orientalis</i> Alef.					
<i>pugnax</i> Alef.	65b	4/11	10 "	9-9	xx
" "	65b	4/18	9 "	4-4	xx
" "	65c	5/16	9 "	10-10	xx
" "	65c	5/23	9 "	10-10	xx
" "	65c	5/30	9 "	10-10	xx
" "	65d	5/16	9 "	10-10	xx
" "	65d	5/23	9 "	10-10	xx
" "	65d	5/30	9 "	10-10	xx
<i>Av. orientalis</i> Schreb.					
<i>tartarica</i> Ard.	5c	4/4	10 "	10-10	xxx
" "	5c	4/11	11 "	10-10	xx
" "	5c	4/18	9 "	10-10	xx
" "	5d	5/16	9 "	10-10	xx
" "	5d	5/23	9 "	7-10	x
" "	5d	5/30	9 "	10-10	xx

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
Av. orientalis Schreb. tartarica Ard.	34b	3/14	8 days	10-10*	xx**
" "	34b	3/21	9 "	2-8	xx
" "	34b	3/28	9 "	10-10	xx
" "	34g	5/16	9 "	10-10	xx
" "	34g	5/23	9 "	10-10	xx
" "	34g	5/30	9 "	4-10	xx
Av. orientalis Alef. tristis Alef.	40	4/25	9 "	10-10	xx
" "	40	5/2	9 "	10-10	xx
" "	40	5/9	9 "	10-10	xx
" "	40b	4/4	10 "	9-9	xx
" "	40b	4/11	9 "	10-10	xx
" "	40b	4/18	9 "	10-10	xx
" "	40c	3/14	8 "	10-10	xx
" "	40c	3/21	--	0-10	--
" "	40c	3/28	9 "	7-7	x
" "	40d	5/16	9 "	10-10	xx
" "	40d	5/23	9 "	10-10	xx
" "	40d	5/30	9 "	10-10	xx
" "	40e	5/16	9 "	10-10	xx
" "	40e	5/23	9 "	10-10	xx
" "	40e	5/30	9 "	10-10	xx

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
<i>Av. orientalis</i> Schreb. Gartons Black	--	4/25	9 days	10-10*	xx**
" "	--	5/2	9 "	10-10	xx
" "	--	5/9	9 "	10-10	xx
Sparrow Bill	--	4/4	10 "	10-10	x
" "	--	4/11	11 "	8-10	xx
" "	--	4/18	9 "	10-10	xx
<i>Av. sativa</i> L. aurea Koke.	7c	4/25	9 "	10-10	xx
" "	7c	5/2	9 "	10-10	xx
" "	7c	5/9	9 "	10-10	xx
" "	7e	5/25	9 "	10-10	xx
" "	7e	5/25	9 "	10-10	xx
" "	7e	5/9	9 "	10-10	xx
" "	7g	3/6	10 "	2-2	x
" "	7g	3/21	--	--	--
" "	7g	3/28	9 "	1-1	xx
" "	7h	4/25	9 "	10-10	xx
" "	7h	5/2	9 "	10-10	xx
" "	7h	5/9	9 "	10-10	xx

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
Av. sativa L. aurea Kcke.	7k	5/16	9 days	10-10*	xx**
" "	7k	5/23	9 "	10-10	xx
" "	7k	5/30	9 "	8-10	xx
" "	7l	5/16	9 "	10-10	xx
" "	7l	5/23	9 "	10-10	xx
" "	7l	5/30	9 "	10-10	xx
aristata Kcke.	42a	4/25	9 "	10-10	xx
" "	42a	5/2	9 "	10-10	xx
" "	42a	5/9	9 "	10-10	xx
brunnea Kcke.	8b	3/6	9 "	10-10	xxx
" "	8b	3/21	9 "	10-10	x
" "	8b	3/28	9 "	10-10	xx
" "	8c	5/16	9 "	10-10	xx
" "	8c	5/23	9 "	10-10	xx
" "	8c	5/30	9 "	10-10	xx
burt (Zavitz)	67	4/4	11 "	10-10	x
" "	67	4/11	11 "	10-10	xx
" "	67	4/18	9 "	10-10	xx
" "	67d	5/16	9 "	10-10	xx
" "	67d	5/23	9 "	10-10	xx
" "	67d	5/30	9 "	10-10	xx

Variety	Seed No.	Date of Inoc.	Incubation Period	No. of Plants Infect.	degree of Infect.
Av. sativa L. burt Zavitz	74c	5/16	9 days	10-10*	xx**
" "	74c	5/23	9 "	10-10	xx
" "	74c	5/30	9 "	10-10	xx
Early Ripe	75	4/4	13 "	10-10	xx
" "	75	4/11	11 "	10-10	xx
" "	75	4/18	9 "	10-10	x
" "	76a	5/16	9 "	10-10	x
" "	76a	5/23	9 "	10-10	xx
" "	76a	5/30	9 "	10-10	xx
Krausei Koke.	9e	3/6	10 "	10-10	x
" "	9e	3/21	9 "	5-5	x
" "	9e	3/28	9 "	6-6	xx
" "	9g	5/16	9 "	10-10	xx
" "	9g	5/23	9 "	10-10	xx
" "	9g	5/30	9 "	10-10	xx
montana Alef.	10d	3/6	9 "	10-10	xx
" "	10d	3/21	9 "	8-10	xx
" "	10d	3/28	9 "	10-10	x
mutica Alef.	11d	3/6	9 "	8-8	xx
" "	11d	3/21	9 "	5-5	x
" "	11d	3/28	9 "	6-6	xx

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
Av. sativa L. mutica Alef.	42a	4/25	9 days	10-10*	xx**
" "	42a	5/2	9 "	10-10	xx
" "	42a	5/9	9 "	10-10	xx
" "	42c	3/14	9 "	10-10	xx
" "	42c	3/21	9 "	1-7	--
" "	42c	3/28	9 "	10-10	xx
" "	43a	4/4	--	0-4	--
" "	43a	4/11	9 "	4-4	xx
" "	43a	4/18	9 "	6-6	xx
" "	43c	5/16	9 "	10-10	xx
" "	43c	5/23	9 "	10-10	xx
" "	43c	5/30	9 "	3-10	x
" "	45a	4/25	9 "	10-10	xx
" "	45a	5/2	9 "	10-10	xx
" "	45a	5/9	9 "	10-10	xx
nigra Kr.	12e	3/14	9 "	10-10	xx
" "	12e	3/21	9 "	8-8	xx
" "	12e	3/28	9 "	10- 10	xx
" "	12g	5/16	9 "	10-10	xx
" "	12g	5/23	9 "	10-10	xx
" "	12g	5/30	9 "	10-10	xx

Variety		Seed No.	Date of Inoc.	Incuba- tion Period	No. of Plants Infect.	Degree of Infect.
Av. sativa L.	nigra Kr.	59a	4/4	11 days	6-6*	x**
"	"	59a	4/11	9 "	4-4	xxx
"	"	59a	4/18	9 "	3-3	xx
praeegravis kr.		13b	4/25	9 "	10-10	xx
"	"	13b	5/2	9 "	10-10	xx
"	"	13b	5/9	9 "	10-10	xx
"	"	13d	3/14	7 "	10-10	x
"	"	13d	3/21	9 "	8-8	xx
"	"	13d	3/28	9 "	7-7	xx
"	"	61	4/25	9 "	10-10	xx
"	"	61	5/2	9 "	10-10	xx
"	"	61	5/9	9 "	10-10	xx
"	"	61a	4/4	11 "	10-10	xx
"	"	61a	4/11	11 "	10-10	x
"	"	61a	4/18	9 "	10-10	xx
setosa Kcke.		14c	4/25	9 "	10-10	xx
"	"	14c	5/2	9 "	10-10	xx
"	"	14c	5/9	9 "	10-10	xx
"	"	14g	3/14	8 "	10-10	xx
"	"	14g	3/21	9 "	6-6	xx
"	"	14g	3/21	9 "	4-4	xx

Variety		Seed	Date	Incubation		No. of	Degree
Av. sativa L.		No.	of	Period		Plants	of
trisperma Schübl.			Inoc.			Infect.	Infect.
		64a	4/4	10	days	5-5*	xx**
"	"	64a	4/11	9	"	5-5	xx
"	"	64a	4/18	9	"	7-7	x
"	"	64b	5/16	12	"	10-10	x
"	"	64b	5/23	11	"	10-10	x
"	"	64b	5/30	11	"	10-10	x
American Banner		--	4/25	9	"	10-10	xx
"	"	--	5/2	9	"	10-10	xx
"	"	--	5/9	9	"	10-10	xx
Big Four		--	4/4	9	"	10-10	xxx
"	"	--	4/11	11	"	10-10	xx
"	"	--	4/18	9	"	10-10	xx
Currell No. 6		--	4/25	9	"	10-10	xx
"	"	--	5/2	9	"	10-10	xx
"	"	--	5/9	9	"	7-7	xx
Czar of Russia		--	4/25	9	"	10-10	xx
"	"	--	5/2	9	"	10-10	xx
"	"	--	5/9	9	"	10-10	xx
Early Illinois		--	4/25	9	"	10-10	xx
"	"	--	5/2	9	"	10-10	xx
"	"	--	5/9	9	"	10-10	xx

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
Avena sativa L. Great Dakota	--	4/25	9 days	10-10*	xx**
" "	--	5/2	9 "	10-10	xx
" "	--	5/9	9 "	10-10	xx
Great Russian	--	4/25	9 "	10-10	xx
" "	--	5/2	9 "	10-10	xx
" "	--	5/9	9 "	10-10	xx
Japan 144	--	4/25	9 "	10-10	xx
" "	--	5/2	9 "	10-10	xx
" "	--	5/9	9 "	10-10	xx
Kherson	--	4/25	9 "	10-10	xx
"	--	5/2	9 "	10-10	xx
"	--	5/9	9 "	10-10	xx
Lincoln	--	4/4	10 "	10-10	xx
"	--	4/11	11 "	10-10	xx
"	--	4/18	9 "	10-10	xx
National	--	4/4	10 "	8-10	xx
"	--	4/11	11 "	8-9	xx
"	--	4/18	9 "	2-10	x
Sensation	--	4/25	9 "	10-10	xx
"	--	5/2	9 "	10-10	xx
"	--	5/9	9 "	10-10	xx

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
<i>Avena sativa</i> L. Silvermine	--	4/25	9 days	10-10*	xx**
"	--	5/2	9 "	10-10	xx
"	--	5/9	9 "	10-10	xx
White Russian	--	4/25	9 "	10-10	xx
" "	--	5/2	9 "	10-10	xx
" "	--	5/9	9 "	10-10	xx
White Shoner	--	4/25	9 "	10-10	xx
" "	--	5/2	9 "	10-10	xx
" "	--	5/9	9 "	10-10	xx
Wide Awake	--	4/25	9 "	10-10	xx
" "	--	5/2	9 "	10-10	xx
" "	--	5/9	9 "	10-10	xx
<i>Avena sterilis</i> L.	27c	3/14	8 "	10-10	xxx
" "	27c	3/27	9 "	1-10	xx
" "	27c	3/28	9 "	10-10	x
" "	27d	5/16	9 "	10-10	xx
" "	27d	5/23	9 "	10-10	xx
" "	27d	5/30	--	0-10	--
" "	27e	5/16	9 "	10-10	x
" "	27e	5/23	9 "	10-10	xx
" "	27e	5/30	9 "	2-10	x

Variety	Seed No.	Date of Inoc.	Incubation Period	No. of Plants Infect.	Degree of Infect.
<i>Avena sterilis</i> L.	28c	4/4	9 days	10-10*	x**
" "	28c	4/11	9 "	6-6	xx
" "	28c	4/18	9 "	6-6	xx
" "	28d	5/16	9 "	10-10	xx
" "	28d	5/23	9 "	10-10	xx
" "	28d	5/30	9 "	5-10	x
Red Rust Proof	--	4/4	10 "	10-10	xx
" " "	--	4/11	11 "	9-9	xx
" " "	--	4/18	9 "	10-10	xx
<i>Avena strigosa</i> Schreb.	29c	5/16	9 "	10-10	xx
" " "	29c	5/23	9 "	10-10	xx
" " "	29c	5/30	9 "	10-10	x
<i>Arrhenatherum avenaceum</i> - Beauv. (<i>Av. elatior</i> L.)		5/4	--	0-many	--
		5/ 23	--	0-many	--
		6/6	--	0-many	--
<i>Festuca elatior</i>	-	5/4	--	0-many	--
" " "		--	--	--	--
" " "		--	--	--	--
<i>Holcus lanatus</i>		5/4	--	0-many	--
" " "		--	--	--	--
" " "		6/6	--	0-many	--

Variety	Seed No.	Date of Inoc.	Incu- bation Period	No. of Plants Infect.	Degree of Infect.
Lolium Italicum	--	5/23	--	0-many	--
" "	--	5/31	--	0-many	--
" "	--	6/6	--	0-many	--
Lolium perenne	--	5/23	--	0-many	--
" "	--	5/31	--	0-many	--

In the above table are recorded the results of 43 varieties belonging to 9 species of Avena. Each variety was used in three or more tests, usually carried out at different times. In some cases the same variety was used under a different seed number. This means that the seed were originally obtained from different sources or that the variety had been grown at Columbia one or more years.

* In each test ten plants were inoculated except in a few cases. In recording the results the first number indicates the number infected and the second the number inoculated.

** The extent of infection in each case was compared with silvermine oats carried out with the same series of experiments. xx indicates that the extent of infection was equal to that on silvermine oats, x indicates less infection, and xxx indicates greater infection.

The usual incubation period of the rust was 9 days. Fully developed pustules with an abundance of uredospores appeared by that time. Evidence of infection however, was available 2 or 3 days earlier. Generally on the 7th day the inoculated leaves showed a considerable number of light colored areas about 1 mm. in diameter. This "flecking" was due to the growth of rust mycelium in the tissue and at these places the pustules broke open from 2 to 3 days later.

In some cases the period of incubation was longer. The period for varieties inoculated April 4 was lengthened from 2 to 3 days. But since the temperature in the greenhouse remained low throughout the period and the weather was cold and cloudy no significance was attributed to this delay. The period for silvermine oats used in the same series of experiments was likewise delayed.

It was also noticed that under the same conditions the incubation period for some varieties was regularly delayed from 1 to 3 days. An example of this is found in the case of Avena sativa var. trisperma which in three tests had incubation periods of 11, 11, and 12 days respectively while in each test the silvermine oats had the normal period of nine days.

The extent of infection was not the same in all tests with some of the varieties. In some tests varieties such as Avena sativa var. burt, Avena orientalis var. obtusata, and about 9 or 10 others had fewer pustules than silvermine oats, although in other tests the extent

of infection was equal to or greater than that of silvermine. No significance can be attributed to these cases.

In other cases the extent of infection was less than that of silvermine oats in more than one test carried out at different times. Varieties thus infected were Avena brevis 1h, Avena orientalis var. tristis 40c, Avena sativa var. krausei 9e, Avena sterilis 27e, and Avena sativa var. trisperma 64b.

The last named variety, Avena sativa var. trisperma, had infection less than that of silvermine oats three times in three different tests. In each test some 20 other varieties along with silvermine oats were tested under exactly the same conditions and each time the extent of infection on variety trisperma was much less than that on any of the 20 other varieties. The pustules were not only few in number and small but also were from 2 to 3 days later in appearing.

The varieties belonging to Avena fatua and Avena ludoviciana all proved to be very susceptible to the rust in the greenhouse. Avena sterilis showed some indications of resistance. In 4 of 6 tests there was apparently less rust. However, the Red Rust Proof variety of Avena sterilis was very susceptible. It is generally believed among growers that Red Rust Proof oats is a resistant variety, while it probably is, instead, a rust escaping variety. It will be noted, as stated before,

that early maturing varieties may escape all or a part of a rust epidemic.

Eriksson states, as noted above on page 9, that a single physiological race of the crown rust is confined to each genus Avena, Alopecurus, Festuca, Holcus, and Lolium and that uredospores produced on any one of these genera will not, except in rare instances, infect any other genus. The work of the writer is in agreement with that of Eriksson in so far as the same genera were tested. Genus Avena was infected with uredospores from Avena but spores from Avena produced no infection in genera Arrhenatherum, Festuca, Holcus, and Lolium.

The results recorded above were obtained under greenhouse conditions which are extremely favorable for rust infection. It was thought that some varieties although very susceptible in the greenhouse might be more or less resistant in the field.

As many of the varieties as could be planted were started in a cold frame which offered conditions similar to field conditions. The frame measures about 5 x 12 feet and is located on the south side of the Biology Building. It is provided with panes of glass which were used to conserve moisture and regulate the temperature during incubation.

The seeds were sowed May 11 in rows six inches apart. When the plants were two weeks old ten pots of stock cultures of rust were taken from the greenhouse and

placed amongst the plants to start infection. Several inoculations were required to produce infection and the plants had 4 to 5 leaves before much rust developed.

The relative percentages of rust were determined by comparing infected leaves with a scale furnished by the Bureau of Plant Industry of the United States Department of Agriculture. The scale shows areas representing 5, 10, 25, 40, 65, and 100 per cent. infection, determined by actual surface covered by rust pustules. The size and number of pustules, in this method, are the factors by which resistance is determined. (a copy of the scale is herewith attached as a plate).

The results of all varieties tested in the cold frame are recorded only in the Summary of Data, pages

Referring to the data, it will be seen that the four varieties, Avena brevis lh, Avena orientalis var. tristis, Avena sativa var. krausei, and Avena sterilis 27e, which had less rust in two of three tests in the greenhouse, in no instance had more than 10 per cent. rust in the cold frame, which was relatively a small amount. The variety which was found most resistant in the greenhouse, Avena sativa var. trisperma matured in the coldframe with less than 5 per cent. of rust

The varieties of Avena fatua and Avena ludoviciana which were found to be very susceptible to rust in the greenhouse developed from 10 to 25 per cent. in the cold frame, which was relatively a high percentage. Avena

sterilis which was less susceptible in the greenhouse developed about 10 per cent.

The genera others than Avena were in no instances infected by uredospores from Avena which, as in the greenhouse experiments, brings out the physiological specialization of the rust.

Further observations on rust resistance were made in the field. Many of the same varieties used in the greenhouse were planted in different plots on the Horticulture and Field Crops Grounds here at Columbia. These varieties were planted for other experiments but through the courtesy of those in charge the writer was given permission to make observations for rust resistance.

The varieties were planted in five plots. In some instances the same variety occurred more than once in the same plot or in one plot and again in another plot. Observations for the amount of rust were made June 24, July 1, and July 8, covering the period in which rust could be found in the plots. At each observation ten leaves were taken from the second and third nodes and the per cent. of rust for each variety, which usually occupied a row, determined by comparing the leaves with the scale for estimating rust (Plate). Results for all varieties are averages taken from the ten leaves and are recorded in the following table:

FIELD OBSERVATIONS

PERCENTAGES OF RUST ON DIFFERENT VARIETIES OF OATS

(Figures are averages of ten leaves taken at random.)

Plot 3

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June	July	July
1	<i>Avena brevis</i> Roth. ¹	1i	July 1 ²	24 5-	1 5-	8 5-
2	<i>Av. orientalis</i> Schreb. <i>obtusata</i>	4b	Aug. 1	5-	5-	25-
3	<i>Av. sativa</i> L. <i>aurea</i> Kcke	7g	"	5-	5-	10
4	<i>Krausei</i> Kcke	9d	"	5-	5-	40-
5	<i>montana</i> Alef.	10c	"	5-	10-	40
6	<i>mutica</i> Alef.	11e	"	5-	10-	10
7	<i>nigra</i>	12d	"	5	25-	dry*
8	<i>praegravis</i>	13d	"	5-	10-	dry
9	<i>setosa</i> Kcke		"	5-	10-	10
10	<i>Av. sterilis</i> L.	27c	"	5-	5-	10
11	<i>Av. strigosa</i> Schreb.	29d	"	5-	5-	dry
12	<i>Av. chinensis</i> Tisch.	30b	June 24	5	25-	dry
13	<i>Av. orientalis</i> Schreb. <i>tartarica</i>	34d	Aug. 1	5-	5-	10
14	<i>tristis</i> Alef.	40c	"	5-	5	10
15	<i>Av. sativa</i> L. <i>mutica</i> Alef.	42b	"	5-	5-	10+
16	<i>mutica</i> Barn.	44a	June 24	5-	5-	25+
17	<i>mutica</i> Polonea	54c	Aug. 1	5-	5-	5+

*Leaves dry at 2d and 3d nodes.

Plot No. 3 cont.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
18	<i>Avena sativa</i> L. mutica Romania	56a	Aug. 1	5-	5	10
19	nigra Kylb.	60a	"	5-	5-	5
20	praegravis Sootia	62a	"	5-	5	25-
21	praegravis Vill.	63a	"	5-	5-	5
22	<i>Av. sterilis</i> L. Burt	67	June 17	5-	5-	dry
23	Burt	74a	"	5-	5	dry
24	Early Ripe	75a	"	5-	5-	dry.

Plot No. 4w.

Horticulture Grounds. Seed planted April 10.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
1	<i>Avena barbata</i> Pott.	76a	June 24	5	0	dry
2	<i>Av. fatua</i> L.	78a	Aug. 1	5-	5	dry
3	<i>Av. ludoviciana</i>	80a	June 24	5-	10	dry
4	<i>Av. nuda</i> L. elegantissima	26b	Aug. 1	5	10-	dry
5	<i>Av. orientalis</i> Schreb. flava	31b	"	5-	5	dry
6	obtusata	33c	"	5-	5-	5+
7	<i>Av. sativa</i> L. brunnea Kcke.	8c	"	5-	5-	dry
8	mutica Alef.	42d	"	5-	5	5+
9	mutica (Belgium)	45b	"	5-	5-	5
10	mutica	51b	"	5-	5-	5-
11	mutica	54d	"	5-	5-	10

Plot No. 4w cont.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
12	<i>Avena sativa</i> L. nigra	60b	Aug. 1	5-	5-	5-
13	<i>Av. sterilis</i> Burt	67d	June 17	5-	5	dry
14	Burt	74c	Aug. 1	5-	5-	10+

Plot No. 4e.

Horticulture Grounds. Seed planted April 10.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
1	<i>Avena brevis</i> Roth.	77a	June 24	5-	5-	dry
2	<i>Av. chinensis</i> Tisch	30c	"	5-	10	dry
3	<i>Av. sativa</i> glabrata	79a	Aug 1	5-	5+	dry
4	<i>Av. nuda</i> L.	25d	"	5-	5-	dry
5	<i>Av. orientalis</i> Schreb. tartica	5d	"	5-	5-	10
6	mutica Koke.	32c	"	0	5-	5-
7	pugnax Alef.	65c	"	5-	5-	5+
8	<i>Av. sativa</i> L. aristata Koke.	35b	"	5-	5-	5+
9	mutica arenaria	43b	June 24	5-	5-	5-
10	mutica	48b	Aug. 1	0	5-	10-
11	mutica	52b	"	5-	5-	5
12	nigra	59a	"	5-	5-	dry
13	trisperma Schubl	64c	"	5-	5-	5
14	nigra	70b	June 24	5-	5+	dry
15	sterilis L.	28d	Aug. 1	0	5-	5+

Plot No. 4e cont.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
16	<i>Avena strigosa</i> Schreb.	29c	June 24	5-	5-	dry

Plot No. 5.

Horticulture Grounds. Seed planted April 12.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
1	<i>Avena barbata</i> Pott	76a	June 17	0	0	dry
2	<i>Av. brevis</i> Roth.	77a	June 24	5-	5-	dry
3	<i>brevis</i> Roth.	1j	"	0	0	dry
4	<i>Av. chinensis</i> Fisch.	30c	"	5-	5	5+
5	<i>Av. fatua</i> L. <i>glabrata</i>	79	"	5-	5	dry
6	<i>Av. fatua</i> L.	78a	Aug. 1	5-	5-	dry
7	<i>Av. ludoviciana</i>	80a	"	5-	5-	10
8	<i>Av. nuda</i> L.	25d	"	5-	5-	dry
9	<i>elegantissima</i>	26b	"	5-	5-	10+
10	<i>Av. orientalis</i> Schreb. <i>tartarica</i>	5d	"	5-	5-	10+
11	<i>flava</i>	31b	"	5-	5-	10III*
12	<i>mutica</i> Koke.	32c	"	5-	5-	15+
13	<i>obtusata</i>	33c	"	5-	5-	10+
14	<i>tartarica</i>	34g	"	5-	5-	10-
15	<i>tristis</i>	40e	"	5-	5	10+
16	<i>pugnax</i> Alef.	65c	"	5-	5	10
17	<i>Av. sativa</i> L. <i>aurea</i> Koke.	7m	"	5-	5-	5III

*III indicates presence of teleutospores

Plot No. 5 cont.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
18	<i>Avena sativa</i> L. bruneum Kcke.	8d	Aug. 1	5-	25	dry
19	Krausei Kcke.	9h	"	5-	10-	25
20	montana Alef.	10e	"	5-	10-	10
21	mutica	11f	"	5-	5-	10
22	nigra Krause.	12f	June 24	10-	25	dry
23	setosa Kcke.	14i	Aug. 1	5-	5-	10
24	<i>Av. sterilis</i> L.	27d	"	5-	5	dry
25	" "	28d	"	0	5-	5+
26	<i>Av. strigosa</i> Schreb.	29c	June 24	0	5-	dry
27	<i>Av. sativa</i> L. aristata Kcke.	35b	Aug. 1	5-	5-	10+
28	grisea Kcke.	41a	"	5-	5-	5+
29	mutica Alef.	42d	"	5-	10-	10
30	mutica	43b	June 24	5-	5	10
31	mutica (Belgium)	45b	Aug. 1	5-	5+	dry
32	mutica (Hirsch)	48b	"	5-	5+	10+
33	mutica	51b	"	5-	10-	dry
34	mutica	52b	"	5-	5+	dry
35	mutica	54d	"	5-	5+	10+
36	nigra	59a	"	5-	5-	25
37	nigra	60b	"	5-	5+	25
38	trisperma	64c	"	0	5-	10-
39	<i>Av. sterilis</i> L. Burt	67d	June 17	5-	5+	dry
40	Burt	67e	"	5-	5+	dry
41	<i>Av. sativa</i> L. nigra	70b	"	5+	40+	dry

Plot No. 5 cont.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust		
				June 24	July 1	July 8
42	<i>Avena sterilis</i> L. Burt	74c	June 17	10†	40	dry
43	Early Ripe	75c	"	5-	10†	dry
44	<i>Av. brevis</i> Roth.	1j	Aug. 1	0	0	dry
45	" "	77a	"	5-	10†	dry
46	<i>Av. fatua</i> L. glabrata	46	"	5	25†	dry
47	<i>Av. fatua</i> L.	78a	"	5†	10†	dry
48	<i>Av. ludoviciana</i>	80a	June 24	5	10†	dry
49	<i>Av. orientalis</i> Schreb. tartarica	5d	"	5-	10-	40
50	flava	31b	Aug. 1	5-	10	25III
51	mutica	32c	"	0	5-	10III
52	obtusata	33c	"	5-	5†	25III
53	tartarica	34g	"	5-	5†	10†
54	tristis	40e	"	5-	10-	dry
55	pugnax Alef.		"	5-	5†	10†
56	<i>Av. sativa</i> L. aurea Kcke.	7m	"	5-	5-	10
57	bruneum Kcke.	8d	"	5-	10†	dry
58	montana Alef.	9h	"	5-	10-	25
59	Krauseii Kcke.	10e	"	5-	25†	dry
60	mutica	11f	"	5-	10-	10†
61	nigra	12f	June 24	10-	25-	dry
62	nigra	14g	Aug. 1	5-	10	10†
63	aristata Kcke.	35b	"	5-	5†	25
64	mutica Alef.	42b	"	5-	10-	10†

Plot No. 5 cont.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust June 24	July 1	July 8
65	<i>Avena sativa</i> L. mutica Alef.	43b	Aug. 1	5-	5	10
66	mutica Alef.	45b	"	5-	10-	10+
67	mutica	48b	"	5-	5	10
68	mutica	51b	"	5-	10-	25-
69	mutica	52b	"	5-	5-	25
70	trisperma	64c	"	0	5-	10+III
71	<i>Av. sterilis</i> L. Burt	67d	June 17	5-	5	dry
72	Burt	67e	"	5-	5	dry
73	<i>Av. sativa</i> L. nigra	70b	"	10-	40	dry
74	<i>Av. sterilis</i> Burt	74c	"	5+	40	dry
75	Early Ripe	75	"	5	25-	dry
76	<i>Av. sterilis</i>	27d	Aug. 1	5-	10	dry
77	" "	28d	"	0	5-	10
78	<i>Av. strigosa</i> Schreb.	29c	June 24	0	5	dry
81-100	Early Champion		June 17	5-	10-	dry

PLOT IN FARM CROPS' FIELD

Seed planted April sixth.

No. Row	Host	Seed No.	Heads ap- peared	Per cent. rust June 24	July 1	July 8
1	Nicholas Black Comet		June 17	5-	10	dryIII
3	Kherson		"	5	5+	"
5	Siberian		June 24	5	10+	"

PLOT IN FARM CROPS' FIELD

CONT.

No. Row	Host	Heads ap- peared	Per cent. rust		
			June 24	July 1	July 8
7	Lincoln	June 24	5-	5†	dryIII
9	Black Orr	June 17	5-	10-	"
11	Big Four	June 24	5-	10	"
15	Garton's Black	"	5-	10	"
17	Great Dakota	"	5-	25-	"
19	White Russian	"	5-	10	"
21	American Banner	Aug. 1	5-	25-	"
23	Czar of Russia	June 24	5-	25-	"
25	Gurrell No. 6	"	5-	25-	"
27	Red Rust Proof	June 17	5	10†	"
29	National	June 24	5-	10	"
31	White Tartar	"	5-	10†	"
33	Early Illinois	"	5-	10†	"
35	Silvermine	"	5	25-	"
37	Early Champion	June 17	5-	10	"
41	Sensation	June 24	5-	10	"
43	White Shoner	"	5-	10	"
45	Early Champion	June 17	5-	10†	"
47	Kherson	"	5-	10†	"
49	Lincoln	June 24	5-	10	"
51	Silvermine	"	5-	10	"
53	Wide Awake	"	5-	10	"
55	Red Rust Proff	June 17	5-	10	"
59	National	June 24	5-	10	"

PLOT IN FARM CROPS' FIELD

CONT.

No. Row	Host	Heads ap- peared	Per cent. rust		
			June 24	July 1	July 8
61	Early Illinois	June 24	5-	5	dryIII
63	White Tartar	"	5-	5½	"

1. The varieties are arranged as they grew in the field and not in alphabetical order.

2. The dates given for the appearance of heads are only approximately correct.

It will be noticed that the varieties in Plot No. 6 are the common cultivated varieties of oats and that all with the exception of one produced heads before August 1. In general these varieties matured earlier than varieties in other plots and none have more than 25- per cent. rust which is relatively a small amount. Silvermine oats and other varieties which are known to be very susceptible to the rust are included. These varieties escaped the rust in part by maturing early. As pointed out above, one method of rust control is to grow early maturing varieties.

Referring to Plot No. 5, rows 40 and 41, it will be noticed that Avena sativa var. burt 67e matured with only 5½ per cent. rust while the variety in the next row, Avena sativa var. nigra 70b, had 40 per cent. at the same time. These same varieties occurred in rows 72 and 73 with variety burt having 5 per cent. rust and the variety nigra having again 40 per cent. The difference in the

amount of rust on the two varieties is very obvious and the fact that the same difference occurred in more than one place in different rows is suggestive of some resisting power on the part of variety burt. Plants with the same seed number were not tested in the greenhouse.

The four varieties which were most resistant in the greenhouse occurred only in part in the field. Avena brevis and Avena orientalis var. tristis occurred in both places. The former matured with no rust in the field while the latter matured with 10 per cent.

A close observation of the table will show that four varieties which were tested in the field but neither in the cold frame nor in the greenhouse had 5 per cent. or less rust. These varieties were Avena nuda 25d, Avena sativa var. nigra 63a, Avena sterilis var. early ripe 63a and Avena strigosa 29b. Since there was much rust in the plots it is peculiar that these varieties did not have more rust. In so far as this test is concerned, though not extensive enough to be very conclusive, the indications are that these varieties are more or less resistant. However, some of the same plants under different number were very susceptible.

By way of a summary of data all results obtained on the different varieties in the greenhouse, cold frame, and field are given briefly in the following table. The results of field observations are given as averages when a variety occurred twice in the same plot or in more than one plot.

SUMMARY OF DATA

A Comparison of Various Varieties of Oats and Related Species in Respect to Amount of Rust under Greenhouse, Coldframe, and Field Conditions.

Host	Seed No.	Plants in Greenhouse		Average % of rust	
		Deg. of Inf'd	Deg. of Inf'n	In Cold Frame	In Field
<i>Avena barbata</i> Pott.	76a ^a	19-30	X--*		
<i>Av. brevis</i> Roth.	1h	19-30	X--		
" "	1i	30-30	X	5	5-**
" "	1j	28-29	X--		0
" "	1k	20-30	X--	5-	
" "	77a	30-30	X	10	5
<i>Av. chinensis</i> Tisch ¹	30b	30-30	X	10	25
" "	30c	20-28	X-		5†
<i>Avena fatua</i> L. glabrata	78a	11-11	X		10-
"	79	18-18	X	25	
"	79a	11-11	X		25†
<i>Av. flavescens</i> Haage	22				
<i>Av. ludoviciana</i> ²	80	30-30	X	10	
" "	80a				10

(a) 19-30 indicates that 19 of 30 inoculated plants were infected.

* X indicates infection of silvermine oats; X- ind. less infection than that of silvermine observed in one series of tests; X-- less inf'n. observed in 2 series of tests; X--- less inf'n. observed in 3 series of tests.

**Averages in case of duplicates.

¹ Probably the same as *Avena nuda* L

² Probably the same as *Avena sterilis*

SUMMARY OF DATA, Cont.

Host	Seed No. No.	Plants in Greenhouse		Average % of rust	
		Deg. of Inf'd	Deg. of Inf'n	In Cold Frame	In Field
<i>Avena ludoviciana</i>	80c	30-30	X	10	
<i>Avena nuda</i> L.	25a	10-10	X--		
" "	25d				5-
" "					
<i>elegantissima</i>	26b	30-30	X	10	10
<i>Av. orientalis</i> Schreb.					
<i>obtusata</i> Alef.	4b	19-26	X-		25
" "	33b	29-29	X	10†	
" "	33c	25-30	X-	5†	10
" "	33d	28-30	X-	10	
<i>flava</i> Koke.	31b	30-30	X-		10
Garton's Black	--	30-30	X	5	10
<i>mutica</i>	32b			25	
<i>pugnax</i>	65b	16-16	X	5†	
"	65c	30-30	X	5	10
"	65d	29-30	X	10	
Sparrow Bill	--	28-30	X-	10	
<i>tartarica</i> ard.	5c	30-30	X	10†	
" "	5d	27-30	X-	10	25
" "	34b	22-28	X		
" "	34d				10
" "	34g	24-30	X	10	10
<i>tristis</i> Alef.	40	30-30	X	25-	
" "	40b	29-29	X	10†	

SUMMARY OF DATA, Cont.

Host	Plants in Greenhouse		Average % of rust		
	Seed No. No.	Deg. of Inf'd Inf'n	In Cold Frame	In Field	
<i>Avena orientalis</i> Schreb.					
tristis Alef.	40c	17-24 X--	5		
" "	40d	30-30 X			
" "	40e		5†	10†	
<i>Avena sativa</i> L.					
American Banner		18-18 X			10†
Aristata Kcke.	35b	10-13 X			15
aurea Kcke.	7c	30-30 X	10		
" "	7e	30-30 X			
" "	7g	2-2 X-			10
" "	7h	30-30 X	5		
" "	7k	30-30 X	10		
" "	7l	30-30 X			
" "	7m				5†
Big Four		27-30 X†	10†		10
Black Orr		30-30 X	10†		10
brunnea Kcke.	8b	22-30 X			
" "	8c	30-30 X	5†		5-
" "	8d				
Currell No. 6		27-27 X			10†
Czar of Russia		30-30 X	5		25-
Early Champion					10
glabrata	79a				
Great Dakota		30-30 X	25-		25-

SUMMARY OF DATA, Cont.

Host	Plants in Greenhouse		Average % of rust		
	Seed No. No.	Deg. of Inf'd Inf'n	In Cold Frame	In Field	
<i>Avena sativa</i> L.					
Green Russian Kan.	27-27	X	10		
<i>grisea</i> Kcke.	41a				5†
Japan 144	30-30	X	10†		
Kherson	30-30	X			10-
<i>krausei</i> Kcke.	9d				
" "	9e	21-21	X--		
" "	9g	30-30	X	5†	
" "	9h				25
Lincoln	28-30	X	25-		10-
<i>montana</i> Alef.	10c	30-30	X	10-	40
" "	10d	28-30	X-	25	
" "	10e				15
<i>mutica</i> Alef.	11d	19-19	X-		
" "	11e				10
" "	11f				10†
" "	42a	30-30	X	10	
" "	42b				10
" "	42c	21-27	X		
" "	42d				10†
" "	43a	10-14	X-		
" "	43b				10-
" "	43c	23-30	X-	10	
" "	44a				25

SUMMARY OF DATA, Cont.

Host	Plants in Greenhouse		Average % of rust	
	Seed No. No.	Deg. of Inf'd Inf'n	In Cold Frame	In Field
<i>Avena sativa</i> L.				
mutica Alef.	45a	30-30 X	10†	
" "	45b			5†
" "	48b			10
" "	51b			10
" "	52b			15
" "	54c			5†
" "	54d			10†
" "	56a			10
National		16-29 X-	10†	10
Nicholas Black Comet				10†
nigra Kr.	12e	28-28 X		
" "	12d			25
" "	12f			25-
" "	12g	30-30 X	10†	
" "	59a	13-13 X		
" "	60a			5-
" "	60b			15
" "	70b			35
praegravis Kr.	13b	30-30 X	10†	
" "	13d	25-25 X-	25	10
" "	61	30-30 X	5-	
" "	61a	30-30 X-	10†	
" "	62a			10

SUMMARY OF DATA, Cont.

Host	Seed No.	Plants in Greenhouse		Average o/o rust	
		No. Inf'd	Deg. of Inf'n	In Cold Frame	In Field
<i>Avena Sativa</i> L.					
<i>praegravis</i> Kr.	63a				5
Sensation		30-30	X	25	
<i>setosa</i> Kcke.	14c	30-30	X	10+	
" "	14g	20-20	X		10+
" "	14i				10
Siberian					10+
Silvermine		30-30	X	25-	15
<i>trisperma</i> Schübl	64a				5-
" "	64b	30-30	X---	5-	
" "	64c				10-
White Russian		30-30	X	10+	10+
White Schoner		30-30	X	10-	
White Tartar		30-30	X	10	10-
Wide Awake		30-30	X	25-	10
<i>Avena sterilis</i> L.	27c	21-30	X	10	10
" "	27e	22-30	X--	10	
" "	27d	20-30	X-	10	
" "	28c	22-22	X-	10	
" "	28d	25-30	X-	5-	10-
burt	67	30-30	X-	5+	5-
"	67d	30-30	X	25-	5
"	67e				5
"	74a				5+
"	74c	30-30	X	25-	5

SUMMARY OF DATA, Cont.

Host	Plants in Greenhouse		Average % of rust	
	Seed No. No.	Deg. of Inf'd Inf'n	In Cold Frame	In Field
<i>Avena sterilis</i> L.				
early ripe Zavitz	75	30-30	X-	
" " "	75a			5-
" " "	75c			15+
" " "	76a	30-30	X-	5
Red Rust Proof		29-29	X	10+
<i>Av. strigosa</i> Schreb.	29b			5
" "	29c	30-30	X-	5
<i>Alopecurus praeterisis</i> Thorburn				
<i>Arrhenatherum avenaceum</i> Beav.*	3a	0-many		
<i>Festuca elatior</i>	3	0-many	0	
<i>Holcus lanatus</i>		0-many	0	
<i>Lolium italicum</i>		0-many	0	0
" perenne		0-many	0	0

*Commonly listed *Avena elatior* L.

The following extract is taken from the Summary of Data to compare the behavior of the varieties which showed less rust in two of three observations in the greenhouse with results obtained in the cold frame and field:

	% rust in Cold frame	% rust in the Field
<i>Avena brevis</i> Roth. 1h	--	--
<i>Avena brevis</i> Roth. 1j	--	0
<i>Avena brevis</i> Roth. 1k	5-	--
<i>Avena orientalis</i> var. <i>tristis</i> 40c	5	--
<i>Avena sativa</i> var. <i>krausei</i> 9e	--	--
<i>Avena sterilis</i> 27e	10	--

Avena brevis is found to be fairly resistant in most observations in the field. *Avena sativa* var. *krausei* 9e was not tested in either the cold frame or field. Some of the same variety but with a different seed number were tested, however, and showed in one instance rust to the extent of 25 per cent.

Avena sativa var. *trisperma* 64b, the most resistant variety in the greenhouse, did not occur in the field. In the cold frame it matured with less than 5 per cent. rust.

Avena strigosa, though giving no appreciable evidence of resistance in the greenhouse, was tested in the field and in two instances appeared more or less resistant.

Vavilov (20), in 1914, found *Avena strigosa* relatively immune to crown rust. Vavilov worked with 323 "pure lines" of *Avena sativa* and found 21 less

susceptible (names of the varieties were not given) and five races belonging to varieties scinerea, brunnea, and grisea relatively immune to crown rust. Of these varieties the writer only tested brunnea which matured with less than 5 per cent. of rust in the cold frame and field.

Vavilov reports varieties of Avena fatua, Avena ludoviciana, and Avena sterilis as very susceptible to crown rust, whereas, the writer finds Avena sterilis more resistant than many other varieties grown at Columbia.

It is interesting to note that Vavilov obtained a different result with stem rust, Puccinia graminis, on oats from that with crown rust on oats. He found 26 of 350 "pure lines" of oats less susceptible to crown rust and 2 of 323 less susceptible to stem rust. One of the two was Avena sativa var. montana which he found less susceptible to crown rust and which the writer found no more resistant than many other varieties.

A further point of interest is found in comparing crown rust with oat mildew, Erysiphe graminis. Reed (17), in 1916, found none of 17 varieties of Avena orientalis and none of 15 varieties of Avena sativa that were not perfectly susceptible to mildew. In the work with crown rust the writer has found a few varieties of Avena sativa more or less resistant. Some infection with mildew was secured on Arrhenatherum avenaceum while the writer got no infection with crown rust. Neither mildew nor crown rust infected Holcus lanatus.

In the mildew, with rare exceptions, each physiological race is confined to a single host species. The wheat mildew is confined to species of Triticum, the oat mildew to species of Avena, etc. This brings out the fact that at least two physiological races of the mildew, the one on Avena and another on Holcus, have the same host genera as two races of the crown rust.

SUMMARY

In the nine species of Avena tested the majority of varieties were found perfectly susceptible to crown rust. Four varieties, Avena brevis Roth., Avena orientalis Schreb. var. tristis 40c, Avena sativa L. var. krausei 9e, and Avena sterilis L. 27e were found to be fairly resistant in both field and greenhouse.

Avena sativa L. var. trisperma 64b was found to be practically immune in the greenhouse but was not tested in the field. In the cold frame this variety matured with less than 5 per cent. rust.

The races of wild oats belonging to species Avena fatua and Avena ludoviciana proved to be very susceptible to crown rust. However, Avena sterilis var. burt and to some extent a few other varieties were more resistant.

Avena nuda L. 25d, Avena sativa L. var. nigra 63a, Avena sterilis L. var. early ripe 63a, and Avena strigosa Schreb. 29d matured in the field with less than 5 per

cent. rust. These varieties were not tested in the greenhouse.

The work as a whole agrees with that done by Vavilov in Russia. In so far as physiological races were determined by the writer they are in agreement with the results obtained by Eriksson. The writer produced infection with uredospores from Avena on Avena but not on species Arrhenatherum, Festuca, Holcus, and Lolium.

In conclusion the writer wishes to express his indebtedness to Dr. George M. Reed for many suggestions and valuable criticisms.

BIBLIOGRAPHY

1. Bolley, H. L. Wheat Rust. Is the infection Local or General in Origin? Agr. Science, 5. 1891.
2. Bolley, H. L. and Pritchard, F. J. Facts, Observations, and Theories; Possible Means of Control. N. D. Agr. Exp. Sta. Bull. 68 1906.
3. Carleton, M. A. Cereal Rusts of the United States. U. S. Dept. Agr. Div. Veg. Path. and Phys. Bull. 16. 1899.
4. Eriksson, Jacob. A General Review of the Principal Results of Swedish Research into Grain Rusts. Bot. Gaz. 25. 1898.
5. ----- Neue Studien über die Spezialisierung der grasbewohnenden Kronenrostarten. Arkiv fur Botanik 8, Band 8, No. 3. 1909.
6. Eriksson and Henning, E. Über die Spezialisierung der Parasitismus bei den Getreiderostpilzen. Berichte der Deutschen Botanischen Gesellschaft 12, 1894.
7. Evans, I. B. Pole. South African Cereal Rusts with Observations on the Problem of Breeding Rust Resistant Wheats. Jour. Agr. Sc. 4. 1912.
8. Freeman, E. M. Resistance and Immunity in Plant Diseases. Phytopathology 1: No. 4. 1911.

9. Freeman, E. M. and Johnson, E. C. The Rusts of
in the United States. U. S. Dept. Agr. Bur.
Plant Ind. Bull. 216. 1911.
10. Fromme, F. D. The Culture of Cereal Rusts. Bulletin
Torry Bot. Club, 40. 1913.
11. Hitchcock A. S. and Carleton, M. A. Preliminary
Report on Rusts of Grains. Kan. Agr. Exp.
Sta. Bull. 38. 1893.
12. Johnson, Edward C. Cardinal Temperatures for
the Germination of Uredospores of Cereal Rusts.
Phytopathology 2. 1912.
13. ----- The Smuts of Wheat, Oats, and
Corn. U. S. Dept. Agr. Bull. 507. 1916.
14. Marryat, Dortha C. E. Notes on Infection and
Histology of two Wheats Immune to the Attack
of Puccinia Glumarum. Jour. Agr. Sc. 2. 1908.
15. McAlpine, D. The Rusts of Australia. 1906.
16. Melhus, I. E. Culturing Parasitic Fungi.
Phytopathology 2. 1912.
17. Reed, George M. The Powdery Mildews of Avena
and Triticum. Mo. Agr. Exp. Sta. Research
Bull. 23. 1916.
18. Stakman, E. C. A Study of Cereal Rusts.
Minn. Agr. Exp. Sta. Bull. 138. 1914.
19. Sydow, P. H. Monographia Uredinearum, 1. 1904.

20. Vavilov, N. D. Immunity of Fungous Diseases as
a Physiological Test in Genetics and Systematics,
Exemplified in Cereals. Jour. of Genetics, 4.
1914.
21. Ward, H. Marshall. On Relation between Host and
Parasite on the Bromes and their Brown Rust.
Ann. Bot. 16. 1902.

SCALE FOR ESTIMATING RUST.

Diagram showing six degrees of rustiness, which may be used in estimating the percentage of rust infection on leaf or stem. The shaded spots represent rust, and the figures represent approximately the rust percentages computed on the basis of the maximum amount of surface covered by rust as shown in the 100% figure. This figure (No. 6 in the diagram) represents 37% of actual surface and is arbitrarily selected as 100%. Other percentages are in terms of No. 6.

This scale is easy of application. A number of leaves are gathered from the row or plat at random, and a number of plants carefully examined for stem rust, these are compared with the diagrams and the proper figures recorded in the notebook.

The plus or minus sign may be used to indicate a slightly greater or less amount of rust than the nearest figure.

While these figures may not express accurately the actual surface of host tissue rusted, they do provide a usable systematic method for recording rust infection, and will more intelligibly represent the facts than will figures showing resistance percentages or infection percentages on the 50% (maximum) basis.

010-100693812

RECEIVED
SEP 5 1917
VIV - MO

378.7M71
XB753

This ~~document is never to go out of this~~
room ~~it is to be checked out~~
~~only~~

mut0391specs

MU Libraries
University of Missouri--Columbia

Digitization Information Page

Local identifier mut0391

Capture information

Date captured	10/2013
Scanner manufacturer	Zeutschel
Scanner model	OS 15000
Scanning system software	Omniscan v.12.4 SR4 (1947) 64-bit
Optical resolution	600 dpi
Color settings	24 bit color
File types	tiff

Source information

Content type	text
Format	book
Source ID	
Notes	

Derivatives - Access copy

Compression	Tiff:compression: 1
Editing software	Adobe Photoshop CS5
Editing characteristics	
Resolution	300 dpi
Color	gray scale / color
File types	pdf
Notes	blank pages removed in pdf