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VARIETAL RESISTANCE AND SUSCEPTIBILITY OF OATS TO POWDERY MILDEW, CROWN RUST AND SMUTS

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VARIETAL RESISTANCE AND SUSCEPTIBILITY OF OATS TO POWDERY MILDEW, CROWN RUST, AND SMUTS

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A well-recognized method of plant-disease control is in the use of varieties of plants which possess a clearly defined resistance to a particular disease. It has long been a matter of observation by plant growers that certain varieties are able to withstand the attacks of a disease which prove to be very serious on other varieties. The discovery and use of such varieties is an obvious way to avoid loss from disease.

The problem of developing resistant varieties is complicated by the fact that physiological host specialization occurs among the parasitic fungi. This phenomenon is of very wide, if not universal, occurrence. The writer[31] has recently summarized the extensive investigations bearing upon this phase of parasitism.

If progress is to be made in breeding disease-resistant varieties it is essential that the resistance or susceptibility toward the parasite be fully determined, and that the possible existence of specialized races of the parasite be worked out. Further, the importance of environmental conditions in the appearance and spread of a disease must be fully recognized; otherwise resistance may be mistaken for mere escape from the disease.

In the present paper the writer brings together a large amount of data on the resistance and susceptibility of species and varieties of Avena to the four diseases—powdery mildew, crown rust, loose and covered smut.

The seed used in these experiments were obtained from various sources. A large number were furnished by Doctor Franz Bubak, Director of the Botanical Garden at Tabor, Bohemia. Seed of several varieties were furnished by C. E. Leighty, J. H. Parker, and T. R. Stanton, Office of Cereal Investigations, U. S. Department of Agriculture. Most of the varieties, however, came from the Farm Crops Department of the University of Missouri. I am specially indebted to Dr. W. C. Etheridge for practically a complete set of the varieties described in his Memoir[8] on the classification of oats.

I am also indebted to Dr. W. E. Maneval, Department of

*Resigned, December, 1918.

Botany, University of Missouri, for looking after the oat-smut plots in 1919. He very kindly supervised the planting and taking of the data and thus made possible the addition of another year's results to the investigations.

All of the experiments with crown rust in 1919 were carried out by Miss Helen Johann, Research Assistant in Botany, University of Missouri. As a result of her careful work the relation of a number of additional varieties of oats were tested with crown rust, as well as further data on varieties tested in previous years.

THE POWDERY MILDEW

Erysiphe Graminis DC. f. Avenae.

Marchal[23] was the first to report results showing the physiological specialization of the powdery mildew of grasses. He established the existence of seven specialized races, one of which occurred on three species of Avena (*A. fatua, A. orientalis, A. sativa*) and on *Arrhenatherum elatius.* This race was not able to infect other hosts such as wheat, barley and rye.

Salmon[33][34] has also carried on some experiments with the oat mildew. Using conidia from *Avena nuda* he infected *A. nuda, A. brevis* and *A. sativa;* conidia from *A. sterilis* infected *A. pratensis* and *A. sativa;* and conidia from *A. sativa* infected *A. sativa, A. brevis, A. nuda, A. orientalis, A. sterilis* and *A. strigosa.* Salmon was unable to transfer the oat mildew to twelve other grasses. He also failed to transfer the oat mildew to *Arrhenatherum elatius,* which Marchal listed as a host for the same mildew as occurs on Avena.

The writer[30] has previously reported the results of extensive experiments with the powdery mildew of oats. The data recorded included tests with forty-one varieties belonging to seventeen species of the genus Avena. Of these varieties, thirty-two were infected in one hundred per cent of the trials, and, in seven additional varieties, the percentage of infection varied from fifty to ninety-eight per cent. Two species, *Avena bromoides* and *A. sempervirens,* gave negative results; in both cases, however, the number of experiments was small. Positive results were obtained with the following: *Avena brevis, A. fatua, A. fatua* var. *glabrata, A. ludoviciana, A. nuda, A. nuda* var. *chinensis, A. nuda* var. *elegantissima, A. planiculmis, A. pratensis, A. pubescens, A. sativa* (sixteen varieties), *A. sativa orientalis* (six varieties), *A. strigosa* and *A. sulcata.* In practically every case the commonly cultivated varie-

ties of oats gave a very high percentage of infection. In fact none of them gave any indication of resistance to the powdery mildew.

The tall meadow oat grass, *Arrhenatherum elatius,* was in fected to a certain extent. The oat mildew can therefore be transferred to this grass. No infection occurred, however, when the oat mildew was sown on *Holcus lanatus, Hordeum vulgare* and *Triticum vulgare.*

These results confirm the work of Marchal and Salmon as to the existence of a well-defined specialized race of *Erysiphe graminis* restricted to the species and varieties of the genus Avena, altho it may also infect *Arrhenatherum elatius.* It is also evident that practically all species and varieties of Avena are highly susceptible to this specialized race of *Erysiphe graminis.*

A large number of additional varieties, belonging to several different species, have been tested as to their susceptibility to the powdery mildew of oats. These experiments have been conducted in the same manner as previously. The plants inoculated were from six to fifteen days old, the first leaf usually being from one to five centimeters long. The spores were dusted on by shaking heavily infected plants over the seedlings. The plants were then kept under glass chambers. Infection was generally evident after three to five days and, at the end of a week, abundant production of conidia occurred on all susceptible hosts.

The original cultures of the oat mildew were obtained from Dr. R. A. Harper, Columbia University. He very kindly furnished cultures on living oat plants on two different occasions. The cultures were continued on oats by keeping a succession of oat seedlings available for inoculation. Fresh stock cultures were started every two to four weeks and these served as a source for an abundant supply of conidia.

During the fall, winter and spring months no difficulty was encountered in keeping on hand excellent stock cultures. In the late spring, however, it became difficult to do so and only by the most careful methods was it possible to keep the oat mildew thruout the summer months.

The results of the writer's work with the powdery mildew of oats are briefly summarized in Table 1. The earlier published results are brought together in the table with those here published for the first time.

TABLE 1.—RESULTS OF INOCULATIONS WITH CONIDIA OF *Erysiphe Graminis* DC. FROM *Avena sativa* L.

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Avena brevis Roth.*	1	21	218	214	98.1
Avena brevis Roth.	77	1	10	10	100
Avena brevis Roth.	134	6	90	90	100
Avena brevis Roth.[1]	135	7	85	75	88.2
Avena bromoides Gouan*	2	7	30	0	0
Avena fatua L.*	78	13	90	90	100
Avena fatua L.	136	6	55	55	100
Avena fatua L.—					
var. *glabrata**	79	4	17	17	100
var. *glabrata*[2]	137	6	91	91	100
var. *glabrata*[3]	138	4	62	62	100
Avena nuda L.*	25	8	48	48	100
Avena nuda L.—					
var. *chinensis**	30	7	42	42	100
var. *elegantissima*	26	6	30	30	100
Avena planiculmis Schrad.*	73	6	48	48	100
Avena pratensis L.*	68	8	61	39	63.9
Avena pubescens Huds.*	6	7	52	34	65.3
Avena purpurea Gueldenst.*	81	4	12	12	100
Avena sativa L.*[4]		3	17	17	100
Avena sativa L.—					
var. *aurea* Kcke.*	7	21	205	191	93.1
var. Awnless Probsteier	114	5	73	73	100
var. Belyak	115	4	61	61	100
var. Black Diamond	116	4	72	72	100
var. Black Mesdag	117	4	72	72	100
var. Black Norway	118	4	56	56	100
var. *brunnea* Kcke.*	8	6	50	50	100
var. Canadian	119	4	57	57	100
var. C. I. 606	127	4	71	71	100
var. Culberson	120	4	67	67	100
var. Green Russian	121	4	87	87	100
var. *grisea* Kcke.*	41	6	62	62	100
var. Joanette	125	4	81	81	100
var. Kherson*	94	2	13	13	100
var. *Krausei* Kcke.*	9	14	110	105	95.4
var. *Montana* Alef.*	10	8	72	72	100
var. North Finnish	123	4	68	68	100
var. *mutica* Alef.*[5]		50	678	678	100
var. *nigra* Kr.*[6]		17	210	210	100
var. *praegravis* Kr.*[7]		20	256	256	100

TABLE 1.—RESULTS OF INOCULATIONS WITH CONIDIA OF *Erysiphe Graminis* DC. FROM *Avena sativa* L. (*Continued*)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Avena sativa L.—					
var. Scottish Chief	124	4	54	54	100
var. Silvermine*	101	9	92	92	100
var. Silvermine	101	1	50	50	100
var. Tobolsk	122	5	108	108	100
var. *trisperma* Schubl.*	64	6	77	77	100
var. Victor	126	6	97	97	100
var. White Tartar*	106	21	348	348	100
Avena sativa orientalis L.*[4]		3	13	13	100
Avena sativa orientalis L.—					
var. Black Tartarian	108	4	64	64	100
var. *flava* Kcke.*	31	7	45	45	100
var. Garton 748	109	4	68	68	100
var. Green Mountain	110	4	59	59	100
var. *mutica* Kcke.*	32	6	40	40	100
var. *obtusata* Alef.*	33	10	69	69	100
var. *pugnax* Alef.*	65	7	84	84	100
var. *setosa**	14	11	98	98	100
var. Sparrowbill	111	5	75	75	100
var. Storm King	112	4	42	42	100
var. *tartarica* Ard.*	34	29	274	268	97.8
var. Tartar King	113	5	72	72	100
var. *tristis* Alef.*	40	8	65	65	100
Avena sempervirens Vill.*	71	2	7	0	0
Avena sterilis L.*[4]	27, 28	23	197	197	100
Avena sterilis L.*[4]	128	4	42	42	100
Avena sterilis L.—					
var. Burt*	67	8	95	95	100
var. Burt	74	2	24	24	100
var. Early Ripe*	75	4	37	37	100
var. Early Ripe	75	2	30	30	100
var. Fulghum	129	4	78	78	100
var. *ludoviciana**	80	6	43	43	100
var. *nigra*	130	4	39	39	100
var. Red Rustproof*	98	3	22	22	100
var. Red Rustproof	131	4	74	74	100
var. Selection	132	4	75	75	100
*Avena strigosa Schreb.**	29	9	88	88	100
Avena strigosa Schreb.*[8]	76	6	53	27	50.9
Avena strigosa Schreb.	76	2	8	5	62.5
Avena strigosa Schreb.	133	6	117	117	100
Avena sulcata F. Gay*	72	7	36	36	100

TABLE 1.—RESULTS OF INOCULATIONS WITH CONIDIA OF *Erysiphe Graminis* DC. FROM *Avena sativa* L. (*Continued*)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Arrhenatherum elatius[4] (L.) Beauv.*		25	450	63	14
Holcus lanatus L.*		4	24	0	0
Lolium multiflorum Lam.	1a	2	90	0	0
Lolium perenne L.	3a	2	80	0	0
Hordeum vulgare L.*		6	92	0	0
Triticum vulgare Vill.*		6	112	0	0

*The star indicates that these results were published in Missouri Agr. Exp. Sta. Research Bulletin 23, 1916.

[1]Late maturing strain.

[2]Grey to black seeded strain.

[3]Yellow seeded strain.

[4]Variety not known.

[5]Includes tests with eighteen collections of this variety, mainly from different localities in Europe.

[6]Includes tests with four collections of this variety, mainly from different localities in Europe.

[7]Includes tests with four collections of this variety, mainly from different localities in Europe.

[8]This was received under the name of *Avena barbata.*

Altogether ninety-eight different varieties or strains have been tested. Of these eighty-eight gave one hundred per cent infection; eight gave fifty to ninety-eight per cent and only two gave negative results. Practically every variety and strain of *A. brevis, A. nuda, A. fatua, A. sativa, A. sativa orientalis, A. sterilis* and *A. strigosa* were fully infected. An occasional plant in some experiments may have escaped infection. *Avena pratensis* and *A. pubescens* have given a somewhat low percentage of infection. The two species, *A. bromoides* and *A. sempervirens,* proved free from infection. Unfortunately the supply of seed was too small to make a large number of experiments.

The oat mildew, to some extent at least, is capable of passing over on to the tall meadow oat grass (*Arrhenatherum elatius*), sixty-three plants out of four hundred and fifty inoculated becoming infected. It does not infect *Holcus lanatus, Lolium multiflorum, L. perenne, Hordeum vulgare* nor *Triticum vulgare.*

It is clear from the foregoing results that, while the oat mildew is highly specialized to the genus Avena and *Arrhenatherum elatius,* it is capable of developing luxuriantly on practically all common species and varieties of Avena. One is impressed with the sharp limitation of the race to this genus, except as noted, and

at the same time, its vigorous development on the species and varieties of this genus. *Avena pratensis, A. pubescens,* and *Arrhenatherum elatius* do not appear to be infected so readily, nor is the growth of the mycelium and production of conidia so abundant on these hosts.

CROWN RUST

Puccinia Coronata Corda.

Crown rust is of very general occurrence thruout the oat-growing sections of the country, east of the Rocky Mountain region. Thruout this section the disease is more or less prevalent every season. Some years it is responsible for very serious damage to the oat crop. Its ravages are generally greater in the southern section as compared with the northern. The introduction of winter oats in the South, which mature sufficiently early, in order to escape the damage done by the disease, is one method of avoiding the losses. In the spring oats section early maturing varieties largely escape the heavy loss. It is, however, highly desirable to secure, if possible, resistant varieties in order to avoid the damage to the oat crop.

Crown rust occurs not only on the species and varieties of Avena, but on a large number of other grasses as well. The fungus is, further, heteroecious, the aecidial stage occurring on various species of *Rhamnus.* It is not at all clear, as yet, the role played by the aecidial host in epidemics of this disease.

Extensive work has been done with the crown rust of grasses from the standpoint of host specialization. The writer[31] has recently summarized the work of Eriksson[5][6][7], Klebahn[14][19], Muhlethaler[24][25], and others along this line. There appears to be in Europe a series of specialized races based upon the aecidial host and, within these races, still others based upon the capacity of the uredospores to infect the various grass hosts.

Carleton[3] has tested the host relations of crown rust on oats and certain grasses. He reports that uredospores from *Avena sativa* can infect *Avena sativa patula, A. sativa orientalis, A. sativa nuda, A. fatua, A. pratensis, Alopecurus alpestris, Aira caespitosa, Anthoxanthum odoratum, Brizopyron siculum, Dactylis glomerata, Eatonia* sp. indet., *Festuca* sp. indet., *Holcus mollis, Koeleria cristata, Phalaris arundinacea, Phleum asperum, Ph. pratense, Poa annua, Polypogon monspeliensis* and *Trisetum subspicatum.* He also infected *Avena sativa* and *Dactylis glomerata* with uredo-

spores from *Phalaris caroliniana*. Further, uredospores from *Arrhenatherum elatius* infected *Avena sativa*.

Treboux[37][38], in southern Russia, found that aecidiospores from *Rhamnus cathartica* infected fifty-one species of grasses belonging to twenty-eight genera. Neither Carleton nor Treboux have found the high degree of specialization reported by the European workers.

Vavilov[39][40] has reported extensive observations as to the susceptibility and resistance of oat varieties to *Puccinia coronata f. avenae* and also to *P. graminis f. avenae*. In his studies he used three hundred and fifty pure lines belonging to twenty-four varieties based on Kornicke's classification. These varieties were distributed among eight species of Avena.

Most of these pure lines were highly susceptible to crown rust. This was specially true of the varieties of *Avena diffusa* (*A. sativa*) and *A. orientalis* most widely used in cultivation, notably the white and yellow seeded sorts. The wild forms of cultivated oats, viz., *A. fatua, A. ludoviciana* and *A. sterilis,* also proved highly susceptible.

The most resistant forms belonged to varieties of *A. diffusa* (*A. sativa*) with brown and grey seeds. *Avena strigosa, A. brevis* and *A. nuda* var. *biaristata* also proved fairly resistant. In all, twenty-four pure lines possessed considerable resistance to crown rust.

Vavilov's work consisted of field observations during the two years 1911 and 1912. His most susceptible varieties were characterized by the appearance of uredo pustules on both lower and upper leaves and, later, by teleuto pustules. His resistant forms, on the other hand, had a few uredo pustules on the lower leaves only, accompanied by more or less flecking of the leaves; no teleuto pustules appeared.

As compared with crown rust only two pure lines gave any well-defined resistance to stem rust—*Puccinia graminis;* these lines belonged to *A. diffusa* var. *brunnea* and *A. diffusa* var. *montana*. All the other pure lines proved to be highly susceptible to the stem rust.

Parker[28] has also studied the behavior of oat varieties to both *Puccinia graminis* and *P. coronata* under greenhouse experimental conditions. He inoculated his plants at two stages of development —in the young seedling stage and at the time when the plants were ready to head out.

Of the one hundred and twenty-two varieties or strains used eighty proved to be entirely susceptible to both rusts in both

stages of development. In fact only two varieties, White Tartarian and Ruakura Rustproof, gave any evidence of resistance to stem rust. On the other hand, a considerable number of strains or varieties showed more or less resistance to the crown rust. Nearly all of these belonged to the *Avena sterilis* group. The resistance, further, was more marked in the later stage of growth than in the seedling stage. As evidence of resistance such points as a longer incubation period, the small size of the uredo pustules and the formation of flecks on the leaves were taken. Parker also emphasizes the fact that teleuto pustules did not appear following abundant production of uredospores. He records the appearance of teleutospores on leaves of seedlings on which uredospores were not produced normally and which gave the other evidences of resistance. It may be noted in passing that the appearance or non-appearance of teleuto pustules is given a different significance by Parker and Vavilov.

Hoerner[11] has recently reported the possible existence of specialized races of crown rust on varieties of Avena. He used cultures of crown rust obtained from a number of localities. He distinguishes four races on the basis of their action on Ruakura Rustproof and Green Russian: (1) Infects both normally; (2) infects both weakly; (3) infects Ruakura weakly and Green Russian normally; (4) infects Ruakura normally and Green Russian weakly.

For several years the writer has carried out inoculation experiments with the crown rust of oats. Cultures were usually obtained in the fall on volunteer oats and carried thru the winter by keeping a supply of seedling oats available and transferring the uredospores to these. Such stock cultures were started anew every three to four weeks.

In the experiments seedlings were used. These were grown in small pots, five to twenty plants in each, until the first green leaf was about two to five centimeters long. The plants were inoculated by dusting over them a large number of uredespores from the stock cultures. In this way large numbers of uredospores fell on the leaves.

The inoculated plants were then placed under bell-jars or larger glass boxes and given ample water and aeration. These conditions proved very favorable for infection. No special effort was made to insure thoro wetting of the leaves as this proved quite unnecessary in order to secure abundant infection.

In six to seven days infection was generally evident by the appearance of large numbers of small yellow-greenish areas on the

inoculated leaves. Two or three days later uredospore pustules pushed through at these points. Generally the pustules broke open and shed uredospores nine days after inoculation.

In most experiments the results with the different varieties were compared carefully with those observed on control plants of the same variety as that from which the uredospores were taken for inoculation.

Most of the experiments were carried out during the fall, winter and spring months of 1916-1917 and 1918-1919. During 1916-1917, W. E. Brentzel[2] carried out independently a large number of tests with several varieties. The 1918-1919 results were very largely obtained by Miss Helen Johann.

The results of these experiments are summarized in Table 2.

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L.

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Avena brevis Roth.*[1]	1	12	119	97	81.5
Avena brevis Roth.	77	11	163	148	90.7
Avena brevis Roth.*	77	3	30	30	100
Avena brevis Roth.	134	4	43	43	100
Avena brevis Roth.	135	4	26	11	42.3
Avena brevis Roth.	142	6	55	55	100
Avena fatua L.	136	3	21	21	100
Avena fatua L.	143	8	69	67	97.1
Avena fatua L.—					
var. *glabrata**	78	3	11	11	100
var. *glabrata**	79	5	29	29	100
var. *glabrata*	137	4	26	26	100
var. *glabrata*	138	6	72	72	100
Avena nuda L.	25	11	128	128	100
Avena nuda L.*	25	1	10	10	100
Avena nuda L.	144	8	36	36	100
Avena nuda L.—					
var. *chinensis*	30	8	86	81	94.1
var. *chinensis**	30	6	60	50	83.3
var. *elegantissima*	26	9	79	74	93.6
var. *elegantissima**	26	3	30	30	100
Avena sativa L.—					
var. American Banner	82	4	45	45	100
var. American Banner*	82	3	30	30	100
var. *aristata**	42	3	30	30	100
var. *aurea**	7	17	153	151	98.6

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (*Continued*)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Avena sativa L.—					
var. Awnless Probsteier....	114	2	16	16	100
var. Belyak	115	3	33	33	100
var. Big Four*	83	3	30	30	100
var. Black Diamond	116	4	36	36	100
var. Black Mesdag	117	2	30	30	100
var. Black Norway	118	2	15	15	100
var. *brunnea*	8	2	25	25	100
var. *brunnea**	8	6	60	60	100
var. Canadian	119	4	57	57	100
var. C. I. 602	145	8	67	67	100
var. C. I. 603	146	9	77	77	100
var. C. I. 606	127	4	54	54	100
var. C. I. 606	147	8	82	82	100
var. C. I. 620	148	7	20	20	100
var. Culberson	120	4	47	47	100
var. Currell No. 6*	87	3	27	27	100
var. Czar of Russia	85	2	28	28	100
var. Czar of Russia*	85	3	30	30	100
var. Danish Island	149	6	29	29	100
var. Early Champion	150	8	90	90	100
var. Early Dakota	151	8	64	64	100
var. Early Gothland	152	8	63	63	100
var. Early Illinois*	86	3	30	30	100
var. Garton	153	8	50	50	100
var. Golden Drop	154	6	44	37	84.0
var. Great Dakota*	89	3	30	30	100
var. Green Russian*	90	3	30	30	100
var. Green Russian	121	2	33	33	100
var. Irish Victor	155	6	51	43	84.3
var. Japan 144	93	3	30	30	100
var. Japan Selection	156	4	27	23	85.1
var. Joanette	125	4	46	46	100
var. June	157	8	61	51	83.6
var. Kherson*	94	3	30	30	100
var. Kherson	158	6	73	73	100
var. Kherson Selection.....	159	8	82	71	86.5
var. *Krausei**	9	6	51	51	100
var. Lincoln*	95	3	30	30	100
var. Lincoln	160	8	44	41	93.1
var. Monarch	161	6	44	44	100
var. Monarch Selection....	162	6	38	37	97.3
var. *montana**	10	3	30	28	93.3

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (*Continued*)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Avena sativa L.—					
var. *mutica**	11	3	19	19	100
var. *mutica**	42	6	57	51	89.4
var. *mutica**	43	6	44	33	75.0
var. *mutica**	45	3	30	30	100
var. *mutica*	51c	1	10	10	100
var. National*	96	3	29	18	62.0
var. *nigra**	12	6	58	58	100
var. *nigra**	59	3	13	13	100
var. North Finnish	123	2	27	27	100
var. Old Island Black	163	8	83	83	100
var. *praegravis**	13	6	55	55	100
var. *praegravis**	61	6	60	60	100
var. Ruakura Rustproof	266	8	93	93	100
var. Scottish Chief	124	2	25	25	100
var. Sensation*	99	3	30	30	100
var. Silvermine	101	8	99	99	100
var. Silvermine*	101	3	30	30	100
var. Silvermine	164	8	44	42	95.4
var. Silvermine Selection	165	8	58	58	100
var. Sixty-Day	166	8	89	89	100
var. Sixty-Day Selection	167	8	61	59	96.7
var. Swedish Select	168	8	27	27	100
var. Tobolsk	122	2	20	20	100
var. *trisperma*	64	6	50	50	100
var. *trisperma**	64	6	47	47	100
var. Victor	126	4	51	51	100
var. White Russian	104	2	20	20	100
var. White Russian*	104	3	30	30	100
var. White Schoenen	105	2	20	13	65
var. White Schoenen*	105	3	30	30	100
var. Wide Awake	107	1	10	10	100
var. Wide Awake*	107	3	30	30	100
var. Winter Turf	169	8	40	40	100
Avena sativa orientalis L.—					
var. Black Tartarian	108	4	29	29	100
var. *flava*	31	2	20	17	85
var. *flava**	31	3	30	30	100
var. Garton 585	170	7	34	30	88.2
var. Garton 748	109	3	26	26	100
var. Garton 784	171	5	14	14	100
var. Garton's Black*	88	3	30	30	100

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (*Continued*)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Avena sativa orientalis L.—					
var. Garton Gray	172	6	19	19	100
var. Golden Giant	173	6	47	47	100
var. Green Mountain	110	4	44	44	100
var. *mutica**	32	3	30	25	83.3
var. *obtusata**	4	3	26	19	73.0
var. *obtusata**	33	9	89	84	94.3
var. *pugnax*	65	2	22	22	100
var. *pugnax**	65	9	76	76	100
var. *setosa**	14	6	50	50	100
var. Sparrowbill*	102	3	30	28	93.3
var. Sparrowbill	111	3	28	28	100
var. Storm King	112	3	23	23	100
var. Tartar King	113	2	12	12	100
var. *tartarica*	5	2	24	24	100
var. *tartarica**	5	6	60	57	95
var. *tartarica**	34	6	58	46	82.7
var. *tristis**	40	15	146	136	93.1
var. White Tartar	174	8	63	62	98.4
Avena sterilis L.*	27	9	90	63	70
Avena sterilis L.	28	4	22	17	77.7
Avena sterilis L.*	28	6	52	47	90.3
Avena sterilis L.	128	12	88	68	77.2
Avena sterilis L.—					
var. Burt	67	4	55	49	89.0
var. Burt*	67	6	60	60	100
var. Burt	74	8	93	75	80.6
var. Burt*	74	3	30	30	100
var. Burt	175	8	58	58	100
var. Burt	254	8	85	85	100
var. Burt	255	8	88	88	100
var. Early Ripe	75	6	70	70	100
var. Early Ripe*	75	6	60	60	100
var. Fulghum	129	6	76	76	100
var. Fulghum	257	8	95	95	100
var. Italian Rustproof	259	6	70	70	100
var. Italian Rustproof	260	6	62	62	100
var. *ludoviciana*	80	5	66	21	31.8
var. *ludoviciana**	80	6	60	60	100
var. *ludoviciana*	176	2	14	14	100
var. nigra	130	11	49	39	79.5
var. Red Rustproof*	98	3	29	29	100
var. Red Rustproof	131	6	55	55	100

TABLE 2.—RESULTS OF INOCULATIONS WITH UREDOSPORES OF *Puccinia coronata* CORDA FROM *Avena sativa* L. (*Continued*)

Host	Seed No.	Total No. Exp.	No. Plants Inoc.	No. Plants Infected	Per cent Infected
Avena sterilis L.—					
var. Selection	132	4	53	53	100
var. Turkish Rustproof	267	6	71	71	100
var. Turkish Rustproof	268	6	68	68	100
Avena strigosa Schreb.	29	8	88	73	82.9
Avena strigosa Schreb.*	29	3	30	30	100
Avena strigosa Schreb.[2]	76	2	36	36	100
Avena strigosa Schreb.	133	7	74	71	95.9
Arrhenatherum elatius (L.) Beauv.		3	60	0	0
Lolium multiflorum Lam.	1a	6	200	0	0
Lolium perenne L.	3a	6	200	1	0.5

[1]The star indicates that the results were obtained by W. E. Brentzel (2) and described in his thesis.

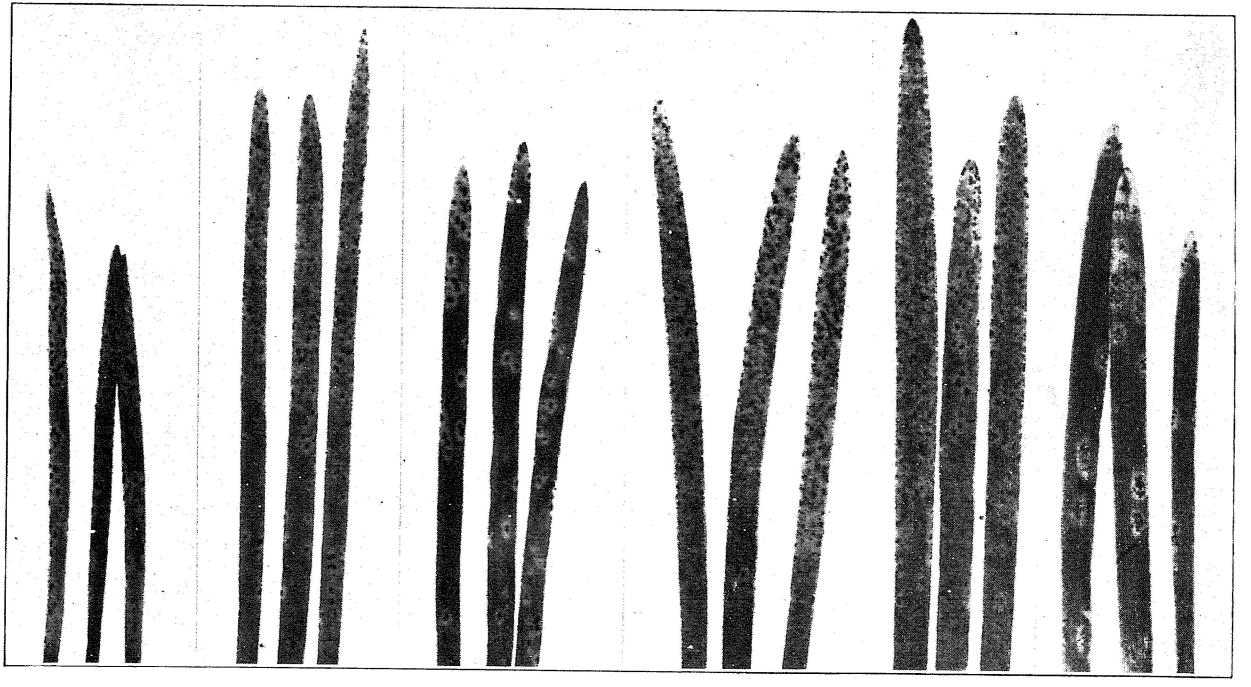
[2]This was received under the name of *Avena barbata*.

In Table 2 are recorded the results with one hundred and thirty-two strains or varieties belonging to seven species of Avena. Each variety was used in two or more experiments. In several cases the same variety was tested in different years as well as at different times during a season.

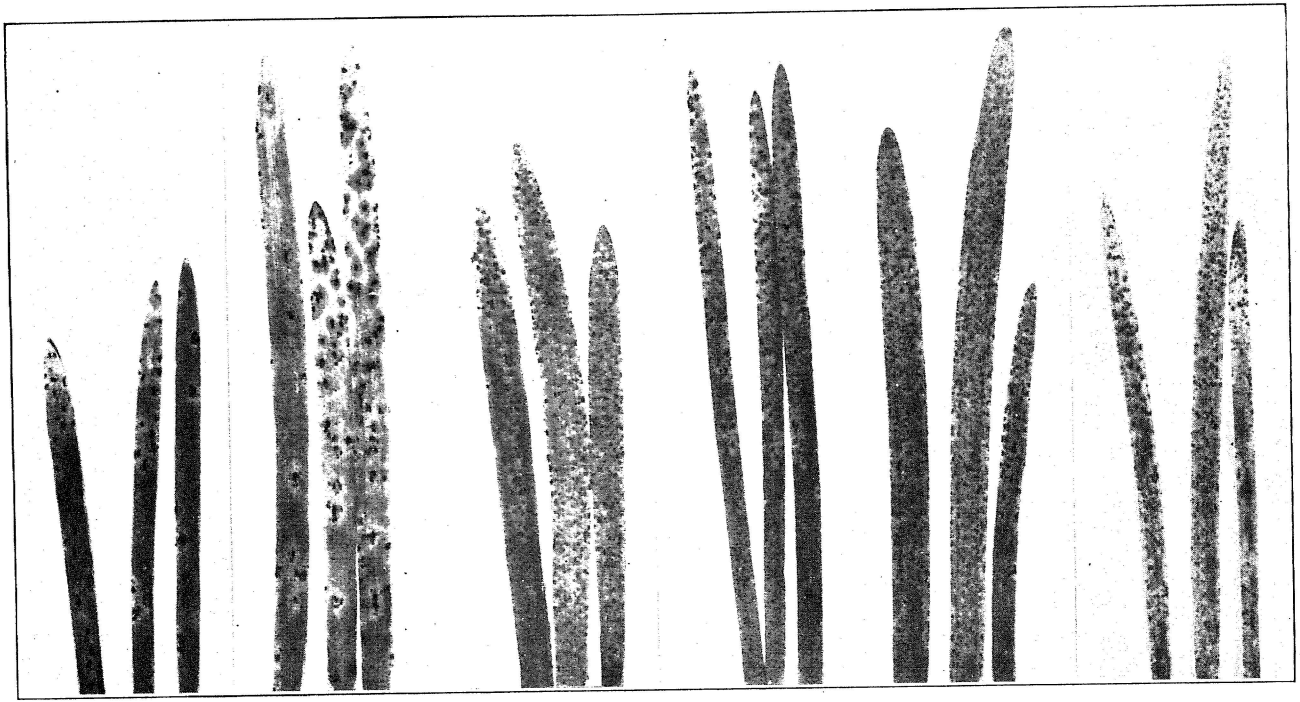
The table includes the results of Brentzel's experiments with fifty-six strains or varieties belonging to seven species. Twenty-one varieties were tested independently by Brentzel and the writer. The methods used, however, were essentially the same.

In recording the results for each individual experiment with a variety a direct comparison was made with well-proved susceptible varieties. In most cases the stock cultures were kept on the same host thruout the season and seedlings of this variety were inoculated in most of the series of experiments, and thus served as a direct basis for comparison. In this way the number of pustules which developed, their size, the time required for the pustules to break open and other points were carefully compared on the different plants.

Due to the very heavy inoculation a large number of uredo pustules appeared on the leaves. These pustules were usually small and round but, where close together, more or less coalesced and became irregular in shape. When fewer pustules appeared



Avena brevis Roth. (77) | *Avena nuda* L. var. *chinensis* (30) | *Avena sativa* L. var. Early Champion (150) | *Avena sativa* L. var. Early Dakota (151) | *Avena sativa* L. var. Garton (153) | *Avena sativa* L. var. Silvermine (164)



Avena sativa L. var. Sixty-Day (166)

Avena sativa L. var. Sixty-Day Selection (167)

Avena sativa L. var. Swedish Select (168)

Avena sativa L. var. Winter Turf (169)

Avena sativa orientalis L. var. Garton 585 (170)

Avena sativa orientalis L. var. White Tartar (174)

Avena fatua L. (143) | *Avena nuda* L. var. elegantissima (26) | *Avena strigosa* Schreb. (29) | *Avena sterilis* L. var. Burt (175) | *Avena sterilis* L. var. Burt (254) | *Avena sterilis* L. var. Fulghum (257)

Avena sterilis L. var. Fulghum (257) | *Avena sterilis* L. var. Italian Rustproof (260) | *Avena sterilis* L. var. Italian Rustproof (260) | *Avena sterilis* L. var. Turkish Rustproof (268) | *Avena sterilis* L. var. Turkish Rustproof (268) | *Avena sativa* L. var. Ruakura Rustproof (266)

on the leaves these were often larger and generally surrounded by a clearly defined light-greenish area.

In several cases, in different experiments, a "flecking" of the leaves occurred, accompanied by relatively few open pustules. This was observed in individual experiments with a considerable number of varieties. In other experiments with the same variety, however, no such flecking was observed; instead large numbers of pustules broke open at the end of the usual incubation period. Such "flecking" did not appear to be characteristic of any variety in all the experiments in which it was used.

In no case did teleuto pustules appear on any of the plants which were kept under observation for two to three weeks after the first appearance of the uredospores. Teleuto pustules were observed only once or twice in the stock cultures which were frequently kept for several weeks after they first became infected.

The incubation period was practically the same in every case. The uredo pustules broke open with great regularity nine days after the plants were inoculated. There were variations from this in different experiments. Only one variety, however, showed any consistent lengthening of the incubation period, namely, *Avena sativa* var. *trisperma*. The uredo pustules on these plants usually broke open one or two days later than on the other varieties inoculated at the same time. In some cases, however, there was no apparent lengthening of the incubation period in this variety.

On examining this table one of the most striking things is the occurrence of one hundred per cent infection with a very large number of varieties. Nine-two varieties were fully infected in every experiment. In all these cases uredo pustules, in greater or less number, broke open on every leaf inoculated. In thirty-four additional varieties infection occurred on seventy-five to ninety-nine per cent of the plants inoculated. In these cases infection failed on one or more plants in a particular experiment or, rarely, negative results were obtained on all plants in one series. Five varieties had fifty to seventy-four per cent of the inoculated plants infected. The remaining variety, a strain of *Avena brevis* (No. 135), gave forty-two per cent infection, eleven out of twenty-six inoculated plants developing typical uredo pustules. A larger number of trials with this strain is desirable to determine whether there is a marked resistance to the rust or whether the low percentage of infection was due to ineffective inoculation. The number of pustules and their general character was the same on the infected

plants as on the completely infected plants of other varieties used in the same experiment.

The number of pustules which developed on the inoculated varieties varied somewhat in the different experiments. This, in large part at least, was due to variation in the number of viable uredospores sown on the leaves. In general there was as much variation in the number of pustules on the varieties used as checks as on any other.

A smaller number of pustules appeared on one strain of *Avena brevis* (No. 1) in a number of experiments. In other experiments, however, there was no apparent difference in this or other respects. As already noted the incubation period was generally longer with *Avena sativa* var. *trisperma*. In this variety also fewer pustules appeared on the inoculated leaves in several experiments than on most of the other varieties used in the same series of experiments. However, all the plants inoculated by both Brentzel and the writer showed open pustules of uredospores.

No experiments were conducted with older plants. Brentzel, however, studied the development of the rust on older plants of a number of varieties. These were planted in a cold frame in early spring and allowed to develop to maturity. The plants were inoculated two or three different times. Later the amount of rust which developed on the leaves was compared. The number of uredo pustules varied considerably. The strain of *Avena brevis* (No. 1), which frequently showed less rust in the greenhouse, had slightly less than most of the varieties. There was also noticeably less rust on *Avena sativa* var. *trisperma* as compared with the others.

The characteristics of the pustules, their number, size, shape, etc., are well shown in the accompanying figures. Considerable differences are to be noted in these respects. In a few cases infected plants of the same variety from different experiments are illustrated. On the same variety, for example, *Fulghum, Italian Rustproof, Ruakura Rustproof* and *Turkish Rustproof,* we sometimes find a very large number of small pustules and, again, a smaller number of somewhat larger pustules. In the latter case the characteristic light-green areas surrounding the cluster of uredospores are quite evident.

A few results are recorded in which uredospores from oats were sown on other grasses. No infection was obtained on *Arrhenatherum elatius* nor *Lolium multiflorum*. A single plant of *Lolium perenne,* in about two hundred inoculated, developed a small uredospore pustule.

THE OAT SMUTS

Ustilago Avenae (Pers.) Jens. and *Ustilago Levis* (K. & S.) Magn.

There are two distinct species of smuts which attack oats—the loose smut, *Ustilago avenae,* and the covered or hidden smut, *Ustilago levis.* The life histories of these two species are similar in all essential respects. In part they may be distinguished by their pathological effects upon the host. The loose smut causes a very complete destruction of the kernel and enclosing glumes. Soon after the oat panicle emerges from the boot the black, dusty spores, with the remnants of the host tissue, are disseminated, leaving a naked, slightly branched panicle. The covered, or hidden smut, also causes the more or less complete destruction of the kernel. The glumes, however, are less involved. They remain more or less persistent and conceal the smut spore masses. The bases of the glumes are, however, more or less attacked and the tissues show blackish, due to the presence of the fungous spores among the host cells.

Frequently it is difficult to distinguish by macroscopic observations between the two smuts. Sometimes the lower spikelets show the external features of *Ustilago avenae,* while the upper have the appearance of *Ustilago levis.* The two species, however, can be separated by microscopic observation of the spores. The spores of *Ustilago levis* are smooth while those of *Ustilago avenae* are minutely echinulate. The spores of both species are about the same size and shape and are lighter colored on one side.

Apparently these two smuts are confined to the genus Avena. A smut very similar to *Ustilago levis* attacks *Arrhenatherum elatius* but it is recognized as a distinct species, partly because of its perennial mycelium.

In the older literature these two species have not been distinguished. Kellerman and Swingle[13] first recognized the differences between them and described the smooth spored variety. Later Magnus[22] gave this form specific rank.

Magnus[22] records in the Mark Brandenburg, Germany, *Ustilago avenae* on *Avena sativa, Avena sterilis, Avena tartarica* and *Avena tartarica* var. *nigra; Ustilago levis* is listed on *Avena sativa* and *Avena nuda.* Lindau[21] later, for the same locality, lists *Ustilago avenae* on *Avena orientalis, Avena sativa, Avena sterilis, Avena strigosa, Avena tartarica* and a hybrid form; *Ustilago levis* is recorded on *Avena nuda* and *Avena sativa.* Clinton[4] in the United States lists *Ustilago avenae* on *Avena sativa* and *Avena fatua,* the smut on the latter host being

recorded only from California; *Ustilago levis* is listed on *Avena sativa*. This species probably is used to include various cultivated varieties which are regarded as belonging to such species as *Avena sativa orientalis* and *Avena sterilis*.

McAlpine[27] reports *Ustilago avenae* on wild oats in Australia. He used spores from wild oats successfully to infect both wild and cultivated oats. He also infected wild oats with spores from cultivated oats. He[26] does not report the occurrence of *Ustilago levis*.

Schellenberg[35] records *Ustilago avenae* on *Avena sativa, Avena orientalis* and *Avena fatua* in Switzerland; *Ustilago levis* is reported on *Avena sativa*.

Lind[20], in Denmark, records *Ustilago avenae* on *Avena sativa, Avena orientalis, Avena fatua* and *Avena fatua* X *Avena sativa; Ustilago levis* is listed on *Avena sativa, Avena orientalis, Avena strigosa* and *Avena strigosa* X *Avena patula*.

Many observations have been recorded indicating the occurrence of oat smut in different varieties. Arthur[1], in New York, notes slight variations in the amount of smut in three different varieties—American Triumph, ten per cent; Board of Trade, eight and five-tenths per cent; New Australian seven to fifteen per cent in different plots. Variable amounts of smut occurred among thirty other varieties. Plumb[29] records from one to three per cent in Race Horse, even when smutted kernels are planted in the soil beside sound grains, as compared with more than nine per cent in White Australian.

Jensen[12], in Denmark, observed the amount of smut in twenty-two varieties during the years 1885, 1886, and 1887. During 1885, the highest per cent recorded was twenty-eight and several varieties were free from smut. In 1886, the highest per cent was forty-five and all varieties were infected to a greater or less extent. In 1887, the highest per cent was seventy-five and again all varieties were infected. The variety Blainsly in general showed the greatest amount of smut. No special efforts were made to inoculate the seed but it is clear that in successive years there was greater contamination of the different varieties. Since there was no inoculation there was no good test for comparative susceptibility. It may be noted, however, that *Avena strigosa,* grown these same years, remained entirely free from smut.

Hickman[9][10], in Ohio, notes the prevalence of smut in a number of varieties of oats. His most extensive report, published in 1895, indicates the amount of smut in sixty-five varieties. Most of these were infected between one and ten per cent; several, however, gave higher percentages. None proved free. Hickman, further, notes the

increase of smut in varieties in successive years due to greater contamination of the seed. Selby[36] has also recorded the occurrence of smut in oat varieties. In 1895, he records the amount in twenty-seven varieties which generally showed high percentages of infection. Various agricultural experiment stations, in bulletins or reports, make more or less casual reference to the prevalence of smut in different varieties of oats.

Zavitz[41][43], in a series of reports, notes the marked freedom of Early Ripe oats from smut. In 1906 Early Ripe, Joanette, Siberian, American Banner and Black Tartarian were free from smut as a result of seed treatment. These varieties were then grown from 1907 to 1914 without any further seed treatment. No efforts were made to inoculate the seed. Further, any smutted plants that appeared in the plots were removed before harvest, thus lessening the chances of inoculation. During these years there was a very marked increase in the amount of smut in Black Tartarian and small amounts in Joanette, Siberian and American Banner. In Early Ripe only one smutted head was found in 1913 and two in 1914.

Rose[32] used sixty-three varieties, planting two sets of seed, one early and the other late in the season. Both sets were carefully inoculated with smut spores. Great differences were noted in the amount of smut in the different varieties. Two varieties, "Schwarzer Brie" and "Oberbrucher," gave negative results. The other varieties gave percentages of infection varying from one and seventy-six hundredths to seventeen and seventy-seven hundredths. In general a higher percentage of infection was obtained in the later planting.

Since 1914, the writer has carried out experiments bearing upon the question of varietal susceptibility and resistance of oats to the loose and covered smuts. In general the dry seed of the oat varieties used were inoculated and then planted in plots as early in the spring as oat plantings could be made. In practically every case one or more rod rows of each variety were planted. The seeding was at a low rate which permitted abundant stooling of the plants. Between fifty and one hundred plants usually matured in the row.

In some of the work the seed was treated, before inoculation, by dipping for about ten minutes in a solution of formaldehyde (one to three hundred and twenty) and covering for a few hours. To a great extent this was not necessary as the seed was collected from clean plots and handled in such a way as to avoid contamination. Occasionally, however, some smut occurred in the check rows which were planted each season, unless the seed had been treated.

Germination tests of the spores used for inoculation were always

made and only those collections which showed a very high rate of germination were used. As stated before, the dry seed was thoroly mixed with a quantity of dry spores. In some cases the seed was first soaked for three to five hours before being inoculated. Immediately after inoculation with the dry spores such pre-soaked seed was planted.

Both loose and covered smut were used each season except that no experiments were carried out with *Ustilago avenae* in 1915 and none with *Ustilago levis* in 1914 and 1917. Separate samples of seed of the varieties were inoculated with the spores of each species of smut and planted in adjacent plots. It was not entirely possible, however, to avoid some mixing of the two smuts during inoculation, planting, etc. In the main, however, each plot contained only the smut whose spores were sown on the seed.

The results obtained during the past six years with loose and covered smuts are summarized in Tables 3 and 4. The tables record the name of the species and variety, the seed identification number, the total number of plants produced and the per cent of plants infected with smut.

Generally a record was kept with reference to the percentage of smutted heads as well as the percentage of smutted plants. The tables, however, are all based on the latter, as plant infection is regarded as the most significant in this connection. As a matter of fact, in practically every case, the percentage of smutted heads was always less than that of the plants, due largely to the fact that smutted plants frequently produced some sound heads. On this account the percentage of smutted heads doubtless represents a more accurate method for determining the loss due to smut.

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS.

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena brevis Roth.	1	105	0	98	0	64	0	11	0	.....	.....
Avena brevis Roth.	77	.....	.....	104	0	89	0	121	0	176	0
Avena brevis Roth.	134	.....	.....	.....	.....	.....	.....	100	0	127	0
Avena fatua L.	78	.....	.....	11	27.3	.....	.....	8	0	.....	.....
Avena fatua L.	143	.....	.....	.....	.....	.....	.....	.....	.....	50	38.0
Avena fatua L.—											
var. *glabrata*	79	.....	.....	27	26.9	.....	.....	.....	.....	.....	.....
Avena nuda L.	25	.....	.....	145	85.0	158	98.1	53	81.1	.....	.....
Avena nuda L.	144	.....	.....	.....	.....	.....	.....	.....	.....	103	49.5
var. *chinensis*	30	19	47.3	123	34.1	125	85.6	94	53.1	144	94.4
var. *elegantissima*	26	.....	.....	192	86.4	32	68.7	100	100.	.....	.....
Avena sativa L.—											
var. Achotatt	.....	425	41.8	.....	.....	.....	.....	.....	.....	.....	.....
var. American Banner	82	.....	.....	.....	.....	93	23.6	105	12.3	.....	.....
var. *aristata*	35	.....	.....	115	9.5	.....	.....	115	6.9	47	8.5
var. *aurea*	7	.....	.....	115	8.7	.....	.....	69	5.7	22	0.
var. Awnless Probsteier	114	.....	.....	.....	.....	.....	.....	73	39.7	30	20.0
var. Belyak	115	.....	.....	.....	.....	.....	.....	90	16.6	18	22.2
var. Big Four	83	.....	.....	.....	.....	.....	.....	115	40.8	.....	.....
var. Black Diamond	116	.....	.....	.....	.....	.....	.....	86	3.4	25	32.0
var. Black Mesdag	117	.....	.....	.....	.....	.....	.....	98	0.	253	0.
var. Black Norway	118	.....	.....	.....	.....	.....	.....	.....	.....	37	10.8
var. Black Orr	84	499	10.8	.....	.....	.....	.....	.....	.....	.....	.....
var. *brunnea*	8	.....	.....	122	13.1	142	9.8	95	21.0	74	25.6
var. Canadian	119	.....	.....	.....	.....	.....	.....	104	37.5	49	47.0
var. C. I. 602	145	.....	.....	.....	.....	.....	.....	.....	.....	49	30.6
var. C. I. 603	146	.....	.....	.....	.....	.....	.....	.....	.....	50	30.0
var. C. I. 606	127	.....	.....	.....	.....	.....	.....	75	4.0	53	1.8

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS. (*Continued*)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa L.—											
var. C. I. 606	147	.....	.....	.....	.....	.....	.....	.....	.....	44	20.4
var. C. I. 620	148	.....	.....	.....	.....	.....	.....	.....	.....	19	5.2
var. Culberson	120	.....	.....	.....	.....	.....	.....	100	60.0	49	6.1
var. Culberson	192	.....	.....	.....	.....	.....	.....	.....	.....	235	10.6
var. Currell No. 6	87	.....	.....	.....	.....	.....	.....	106	39.6	.....	.....
var. Czar of Russia	85	427	51.2	.....	.....	.....	.....	129	49.6	.....	.....
var. Danish Island	149	.....	.....	.....	.....	.....	.....	.....	.....	43	37.2
var. Early Champion	.....	542	72.8	77	9.0	.....	.....	.....	.....	.....	.....
var. Early Champion	150	.....	.....	.....	.....	.....	.....	.....	.....	62	38.7
var. Early Champion	197	.....	.....	.....	.....	.....	.....	.....	.....	272	41.5
var. Early Dakota	151	.....	.....	.....	.....	.....	.....	.....	.....	58	29.3
var. Early Gothland	152	.....	.....	.....	.....	.....	.....	.....	.....	31	67.7
var. Early Illinois	86	.....	.....	.....	.....	.....	.....	85	20.0	.....	.....
var. Garton	153	.....	.....	.....	.....	.....	.....	.....	.....	30	60.0
var. Golden Drop	154	.....	.....	.....	.....	.....	.....	.....	.....	52	21.1
var. Great Dakota	89	435	51.0	.....	.....	133	18.7	95	57.8	.....	.....
var. Green Russian	90	.....	.....	.....	.....	.....	.....	97	24.7	.....	.....
var. Green Russian	121	.....	.....	.....	.....	.....	.....	84	38.0	97	13.9
var. *grisea*	41	.....	.....	54	22.2	.....	.....	73	24.6	.....	.....
var. Iowa 103	91	.....	.....	.....	.....	.....	.....	101	36.6	.....	.....
var. Iowa 105	92	.....	.....	.....	.....	.....	.....	96	8.3	.....	.....
var. Irish Victor	155	.....	.....	.....	.....	.....	.....	.....	.....	45	22.2
var. Japan 144	93	.....	.....	.....	.....	.....	.....	109	21.1	.....	.....
var. Japan Selection	156	.....	.....	.....	.....	.....	.....	.....	.....	57	57.8
var. Joanette	125	.....	.....	.....	.....	.....	.....	53	35.8	60	10.0
var. June	157	.....	.....	.....	.....	.....	.....	.....	.....	35	60.0
var. Kherson	94	.....	.....	.....	.....	80	17.5	73	24.6	.....	.....

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS. (*Continued*)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa L.—											
var. Kherson	158	.....	.....	.....	.....	.....	.....	.....	.....	49	42.8
var. Kherson Selection	159	.....	.....	.....	.....	.....	.....	.....	.....	54	44.4
var. *krausei*	9	.....	.....	100	0	25	12.0	37	2.7	12	0
var. Lincoln	95	457	47.0	.....	.....	116	5.1	108	25.9	.....	.....
var. Lincoln	160	.....	.....	.....	.....	.....	.....	.....	.....	48	35.4
var. Minnesota No. 270	.....	352	39.5	.....	.....	.....	.....	.....	.....	.....	.....
var. Monarch	.....	795	40.8	.....	.....	.....	.....	.....	.....	.....	.....
var. Monarch	161	.....	.....	.....	.....	.....	.....	.....	.....	57	0.
var. Monarch Selection	162	.....	.....	.....	.....	.....	.....	.....	.....	22	54.5
var. *montana*	10	.....	.....	127	5.5	91	3.2	99	10.1	22	4.5
var. *mutica*	11	.....	.....	114	14.9	.....	.....	84	11.9	.....	.....
var. *mutica*	42	.....	.....	76	38.1	.....	.....	68	45.5	63	14.2
var. *mutica*	43	.....	.....	168	13.1	137	14.5	104	46.1	55	20.0
var. *mutica*	45	.....	.....	112	3.5	126	0.	100	1.0	49	4.0
var. *mutica*	46	.....	.....	.....	.....	.....	.....	110	19.0	24	12.5
var. *mutica*	47	.....	.....	.....	.....	.....	.....	115	43.4	51	21.5
var. *mutica*	48	.....	.....	128	18.7	.....	.....	121	33.8	54	29.6
var. *mutica*	49	.....	.....	.....	.....	.....	.....	92	22.8	3	33.3
var. *mutica*	50	.....	.....	.....	.....	.....	.....	117	23.0	.....	.....
var. *mutica*	51	.....	.....	102	13.7	.....	.....	108	29.6	65	6.1
var. *mutica*	52	.....	.....	88	2.2	.....	.....	106	54.7	34	5.8
var. *mutica*	53	.....	.....	.....	.....	.....	.....	93	41.9	16	43.7
var. *mutica*	54	.....	.....	157	26.5	.....	.....	60	36.6	3	0.
var. *mutica*	55	.....	.....	.....	.....	.....	.....	86	26.7	2	50.0
var. *mutica*	56	.....	.....	.....	.....	.....	.....	109	33.0	.....	.....
var. *mutica*	57	.....	.....	.....	.....	.....	.....	118	15.2	53	3.7
var. *mutica*	58	.....	.....	.....	.....	.....	.....	105	20.0	52	7.7

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS. (*Continued*)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa L.—											
var. National	96	457	30.4	.....	.....	.....	.....	75	17.3	.....	.....
var. Nichol's Black Comet	97	.....	.....	.....	.....	.....	.....	96	37.5	.....	.....
var. *nigra*	12	.....	.....	97	9.3	11	0.	51	45.1	.....	.....
var. *nigra*	56	.....	.....	.....	.....	.....	.....	.....	.....	16	37.5
var. *nigra*	59	.....	.....	60	3.3	.....	.....	100	10.0	15	13.3
var. *nigra*	60	.....	.....	68	8.8	.....	.....	.....	.....	.....	.....
var. *nigra*	70	.....	.....	65	0.	.....	.....	100	0.	290	0.
var. North Finnish	123	.....	.....	.....	.....	.....	.....	108	38.8	96	6.2
var. Old Island Black	163	.....	.....	.....	.....	.....	.....	.....	.....	56	8.9
var. *praegravis*	13	.....	.....	.....	.....	.....	.....	77	46.7	.....	.....
var. *praegravis*	61	.....	.....	.....	.....	.....	.....	103	25.2	29	34.4
var. *praegravis*	62	.....	.....	.....	.....	.....	.....	121	23.9	22	36.3
var. Scottish Chief	124	.....	.....	.....	.....	.....	.....	77	14.2	47	17.0
var. Sensation	99	.....	.....	.....	.....	.....	.....	95	23.1	.....	.....
var. Siberian	100	.....	.....	.....	.....	.....	.....	54	31.4	.....	.....
var. Silvermine	101	338	49.1	.....	.....	133	14.2	67	43.2	.....	.....
var. Silvermine	164	.....	.....	.....	.....	.....	.....	.....	.....	36	16.6
var. Silvermine Selection	165	.....	.....	.....	.....	.....	.....	.....	.....	41	22.0
var. Sixty-Day	166	.....	.....	.....	.....	.....	.....	.....	.....	59	35.5
var. Sixty-Day Selection	167	.....	.....	.....	.....	.....	.....	.....	.....	60	8.3
var. Swedish Select	168	.....	.....	.....	.....	.....	.....	.....	.....	27	29.6
var. Tobolsk	122	.....	.....	.....	.....	.....	.....	100	4.0	59	18.6
var. *trisperma*	64	.....	.....	73	16.4	.....	.....	85	5.8	8	12.5
var. Victor	126	.....	.....	.....	.....	137	17.5	82	47.5	28	46.4
var. White Queen	103	.....	.....	.....	.....	.....	.....	68	51.4	.....	.....
var. White Russian	104	.....	.....	.....	.....	.....	.....	86	39.5	.....	.....
var. White Schoenen	105	1138	25.3	.....	.....	.....	.....	76	39.4	.....	.....

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS (*Continued*)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa L.—											
var. Wide Awake	107	438	35.6	.....	.....	118	7.6	103	24.2	.....	.....
var. Wisconsin Wonder	.....	389	31.6	.....	.....	.....	.....	.....	.....	.....	.....
Avena sativa orientalis L.—											
var. Black Tartarian	108	.....	.....	.....	.....	.....	.....	96	5.2	59	20.3
var. *flava*	31	.....	.....	71	15.5	.....	.....	93	17.2	38	15.8
var. Garton 585	170	.....	.....	.....	.....	.....	.....	.....	.....	18	11.0
var. Garton 748	109	.....	.....	.....	.....	.....	.....	114	30.7	65	18.4
var. Garton	171	.....	.....	.....	.....	.....	.....	.....	.....	21	33.3
var. Garton's Black	88	477	44.2	.....	.....	.....	.....	100	56.0	.....	.....
var. Garton Gray	172	.....	.....	.....	.....	.....	.....	.....	.....	29	38.0
var. Golden Giant	173	.....	.....	.....	.....	.....	.....	.....	.....	50	16.0
var. Green Mountain	110	.....	.....	.....	.....	.....	.....	98	40.8	38	47.3
var. *mutica*	32	.....	.....	92	9.8	.....	.....	94	36.1	57	21.0
var. *obtusata*	4	34	52.9	.....	.....	.....	.....	.....	.....	.....	.....
var. *obtusata*	33	.....	.....	82	4.8	140	6.4	118	14.4	57	17.5
var. *pugnax*	65	16	25.0	126	37.3	104	9.6	85	15.2	5	60.0
var. *pugnax*	66	30	36.6	.....	.....	.....	.....	.....	.....	.....	.....
var. *setosa*	14	.....	.....	141	16.3	.....	.....	86	10.4	15	0.
var. Sparrowbill	111	.....	.....	.....	.....	.....	.....	90	14.4	48	25.0
var. Sparrowbill	102	.....	.....	.....	.....	.....	.....	100	43.0	.....	.....
var. Storm King	112	.....	.....	.....	.....	.....	.....	84	11.9	36	27.7
var. *tartarica*	5	.....	.....	122	13.9	118	22.0	82	20.7	.....	.....
var. *tartarica*	34	.....	.....	133	17.3	.....	.....	.....	.....	.....	.....
var. Tartar King	113	.....	.....	.....	.....	.....	.....	79	11.3	46	17.3
var. *tristis*	40	4	0.	136	2.9	.....	.....	105	17.0	24	41.6
var. White Tartar	106	262	22.9	.....	.....	.....	.....	63	28.5	.....	.....
var. White Tartar	174	.....	.....	.....	.....	.....	.....	.....	.....	38	34.2

TABLE 3.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Avenae* (PERS.) JENS. (*Continued*)

Species and Variety	Seed No.	1914		1916		1917		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sterilis L.	27	18	5.5	89	11.2	.....	.....	18	38.8	.....	.....
Avena sterilis L.	28	12	0..	130	0.	.....	.....	54	5.5	5	0.
Avena sterilis L.—											
var. Burt	67	359	2.5	215	0.	156	0.	68	4.4	83	1.2
var. Burt[1]	74	412	30.0	63	4.7	.....	.....	94	18.0	111	6.3
var. Burt	175	.....	.....	.....	.....	.....	.....	.....	.....	31	0.
var. Burt	253	.....	.....	.....	.....	.....	.....	.....	.....	142	3.6
var. Early Ripe[2]	75	377	8.4	113	2.6	20	0.	100	5.0	142	6.2
var. Fulghum	129	.....	.....	.....	.....	.....	.....	100	0.	205	0.
var. Fulghum	257	.....	.....	.....	.....	.....	.....	.....	.....	194	1.9
var. Italian Rustproof	260	.....	.....	.....	.....	.....	.....	.....	.....	60	3.3
var. ludoviciana	80	.....	.....	102	4.9	103	9.7	91	3.3	.....	.....
var. ludoviciana	176	.....	.....	.....	.....	.....	.....	.....	.....	29	0.
var. nigra	130	.....	.....	.....	.....	.....	.....	.....	.....	26	0.
var. Red Rustproof	98	.....	.....	.....	.....	125	10.4	76	32.8	.....	.....
var. Red Rustproof	131	.....	.....	.....	.....	.....	.....	.....	.....	19	10.5
var. Selection	132	.....	.....	.....	.....	.....	.....	90	4.4	50	4.0
var. Turkish Rustproof	267	.....	.....	.....	.....	.....	.....	.....	.....	50	0.
var. Turkish Rustproof	268	.....	.....	.....	.....	.....	.....	.....	.....	48	0.
Avena strigosa Schreb.	29	25	0.	105	0.	81	0.	100	0.	254	0.
Avena strigosa Schreb.[3]	76	.....	.....	118	0.	76	0.	100	0.	173	0.
Avena strigosa Schreb.	133	.....	.....	.....	.....	.....	.....	100	0.	115	0.

[1]This variety does not resemble very closely the other Burt strains.
[2]This variety resembles very closely Burt (74).
[3]This strain was received under the name of *Avena barbata*.

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN.

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena brevis Roth.	1	275	0.	130	0.	.....	.....	.....	.....
Avena brevis Roth.	77	.....	.....	120	0.	100	0.	127	0.
Avena brevis Roth.	134	.....	.....	.....	.....	100	0.	144	0.
Avena fatua L.	78	.....	.....	23	17.4	3	0.	.....	.....
Avena fatua L.	143	.....	.....	.....	.....	.....	.....	51	60.7
Avena fatua L.—									
var. *glabrata*	79	.....	.....	20	40.	.....	.....	.....	.....
Avena nuda L.	25	.....	.....	.....	.....	80	97.5	.....	.....
Avena nuda L.	144	.....	.....	.....	.....	.....	.....	99	65.6
Avena nuda L.—									
var. *chinensis*	30	.....	.....	.....	.....	75	8.0	108	92.5
var. *elegantissima*	26	42	73.8	.....	.....	80	22.5	.....	.....
Avena sativa L.—									
var. American Banner	82	.....	.....	.....	.....	85	56.4	.....	.....
var. *aristata*	35	.....	.....	101	5.9	108	19.4	45	13.3
var. *aurea*	7	98	3.0	94	19.1	.....	.....	12	0.
var. Awnless Probsteier	114	.....	.....	.....	.....	74	18.9	27	11.1
var. Belyak	115	.....	.....	.....	.....	79	10.1	21	28.5
var. Big Four	83	.....	.....	.....	.....	92	42.3	.....	.....
var. Black Diamond	116	.....	.....	.....	.....	90	2.2	24	8.3
var. Black Mesdag	117	.....	.....	.....	.....	93	0.	289	0.
var. Black Norway	118	.....	.....	.....	.....	.....	.....	37	0.
var. Black Orr	84	.....	.....	.....	.....	95	10.5	.....	.....
var. *brunnea*	8	58	5.1	117	31.6	81	18.5	66	4.5
var. Canadian	119	.....	.....	.....	.....	95	81.0	45	53.3
var. C. I. 602	145	.....	.....	.....	.....	.....	.....	40	0.
var. C. I. 603	146	.....	.....	.....	.....	.....	.....	50	54.0
var. C. I. 606	127	.....	.....	.....	.....	75	2.6	53	18.8

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (*Continued*)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa L.—									
var. C. I. 606	147	.....	.....	.....	.....	.....	.....	56	33.9
var. C. I. 620	148	.....	.....	.....	.....	.....	.....	13	53.8
var. Culberson	120	.....	.....	.....	.....	85	23.5	54	14.8
var. Culberson	192	.....	.....	.....	.....	.....	.....	262	12.2
var. Currell No. 6	87	.....	.....	.....	.....	86	10.4	.....	.....
var. Czar of Russia	85	.....	.....	.....	.....	84	46.4	.....	.....
var. Danish Island	149	.....	.....	.....	.....	.....	.....	45	15.5
var. Early Champion	.....	758	36.0	104	10.5	.....	.....	.....	.....
var. Early Champion	150	.....	.....	.....	.....	.....	.....	68	82.3
var. Early Champion	197	.....	.....	.....	.....	.....	.....	266	42.8
var. Early Dakota	151	.....	.....	.....	.....	.....	.....	55	38.1
var. Early Gothland	152	.....	.....	.....	.....	.....	.....	45	2.2
var. Early Illinois	86	.....	.....	.....	.....	100	29.0	.....	.....
var. Garton	153	.....	.....	.....	.....	.....	.....	25	28.0
var. Golden Drop	154	.....	.....	.....	.....	.....	.....	48	50.0
var. Great Dakota	89	.....	.....	.....	.....	107	13.0	.....	.....
var. Green Russian	90	.....	.....	.....	.....	99	10.1	.....	.....
var. Green Russian	121	.....	.....	.....	.....	99	17.1	96	20.8
var. *grisea*	41	.....	.....	.....	.....	110	20.0	.....	.....
var. Iowa 103	91	.....	.....	.....	.....	80	43.7	.....	.....
var. Iowa 105	92	.....	.....	.....	.....	82	29.2	.....	.....
var. Irish Victor	155	.....	.....	.....	.....	.....	.....	48	45.8
var. Japan 144	93	.....	.....	.....	.....	95	14.7	.....	.....
var. Japan Selection	156	.....	.....	.....	.....	.....	.....	79	67.0
var. Joanette	125	.....	.....	.....	.....	67	19.4	65	15.5
var. June	157	.....	.....	.....	.....	.....	.....	46	58.7
var. Kherson	94	256	23.0	.....	.....	75	32.0	.....	.....

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (*Continued*)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa L.—									
var. Kherson	158	.....	.....	.....	.....	.....	.....	25	46.1
var. Kherson Selection	159	.....	.....	.....	.....	.....	.....	59	69.4
var. *krausei*	9	120	0.	136	19.1	40	40.0	8	37.5
var. Lincoln	95	.....	.....	.....	.....	92	23.9	.....	.....
var. Lincoln	160	.....	.....	.....	.....	.....	.....	40	45.0
var. Monarch	161	.....	.....	.....	.....	.....	.....	44	61.3
var. Monarch Selection	162	.....	.....	.....	.....	.....	.....	26	0.
var. *montana*	10	144	2.0	104	1.9	69	21.7	18	16.6
var. *mutica*	11	.....	.....	80	0.	.....	.....	.....	.....
var. *mutica*	42	84	4.7	95	17.9	59	13.5	39	0.
var. *mutica*	43	.....	.....	104	5.7	91	25.2	45	11.1
var. *mutica*	45	.....	.....	84	0.	100	2.0	47	0.
var. *mutica*	46	.....	.....	.....	.....	100	1.0	32	3.1
var. *mutica*	47	.....	.....	.....	.....	99	26.2	58	1.7
var. *mutica*	48	.....	.....	98	14.3	87	27.5	52	11.5
var. *mutica*	49	.....	.....	.....	.....	80	25.0	5	0.
var. *mutica*	50	.....	.....	.....	.....	91	12.0	.....	.....
var. *mutica*	51	.....	.....	86	16.3	82	32.9	57	1.7
var. *mutica*	52	.....	.....	73	6.8	86	23.2	37	2.7
var. *mutica*	53	.....	.....	.....	.....	108	23.1	6	16.6
var. *mutica*	54	.....	.....	.....	.....	75	36.0	3	33.3
var. *mutica*	55	.....	.....	.....	.....	81	22.2	3	33.3
var. *mutica*	56	.....	.....	.....	.....	85	34.1	18	22.2
var. *mutica*	57	.....	.....	.....	.....	72	16.6	54	0.
var. *mutica*	58	.....	.....	.....	.....	100	48.0	46	2.1
var. National	96	.....	.....	.....	.....	93	16.1	.....	.....
var. Nichol's Black Comet	97	221	21.7	.....	.....	90	37.7	.....	.....

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (*Continued*)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa L.—									
var. *nigra*	12	120	0.	89	3.3	26	15.3	.....	.....
var. *nigra*	59	.....	.....	.....	.....	122	0.	19	0.
var. *nigra*	70	.....	.....	115	0.	100	0.	324	0.
var. North Finnish	123	.....	.....	.....	.....	71	29.5	81	34.5
var. Old Island Black	163	.....	.....	.....	.....	.....	.....	69	24.0
var. *praegravis*	13	.....	.....	.....	.....	71	50.7	.....	.....
var. *praegravis*	61	.....	.....	.....	.....	98	27.5	39	30.7
var. *praegravis*	62	102	7.8	.....	.....	117	28.2	25	8.0
var. Scottish Chief	124	.....	.....	.....	.....	59	10.1	47	0.
var. Sensation	99	.....	.....	.....	.....	83	22.8	.....	.....
var. Siberian	100	.....	.....	.....	.....	81	27.1	.....	.....
var. Silvermine	101	166	9.0	.....	.....	59	22.0	.....	.....
var. Silvermine	164	.....	.....	.....	.....	.....	.....	31	35.4
var. Silvermine Selection	165	.....	.....	.....	.....	.....	.....	59	35.5
var. Sixty-Day	166	.....	.....	.....	.....	.....	.....	46	54.3
var. Sixty-Day Selection	167	.....	.....	.....	.....	.....	.....	47	29.7
var. Swedish Select	168	.....	.....	.....	.....	.....	.....	31	45.1
var. Tobolsk	122	.....	.....	.....	.....	120	37.5	82	41.4
var. *trisperma*	64	120	0.	80	5.0	85	21.1	8	0.
var. Victor	126	.....	.....	.....	.....	66	21.2	24	66.6
var. White Queen	103	.....	.....	.....	.....	100	3.0	.....	.....
var. White Russian	104	.....	.....	.....	.....	111	31.5	.....	.....
var. White Schoenen	105	.....	.....	.....	.....	90	12.2	.....	.....
var. Wide Awake	107	.....	.....	.....	.....	71	38.0	.....	.....
Avena sativa orientalis L.—									
var. Black Tartarian	108	.....	.....	.....	.....	94	41.4	47	12.7
var. *flava*	31	.....	.....	114	17.6	.....	.....	26	23.0

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (*Continued*)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sativa orientalis L.—									
var. Garton's Black	88	.....	.....	.....	.....	87	4.6	.....	.....
var. Garton 585	170	.....	.....	.....	.....	.....	.....	18	44.4
var. Garton 748	109	.....	.....	.....	.....	100	49.0	60	15.0
var. Garton	171	.....	.....	.....	.....	.....	.....	18	22.2
var. Garton Gray	172	.....	.....	.....	.....	.....	.....	20	70.0
var. Golden Giant	173	.....	.....	.....	.....	.....	.....	46	45.6
var. Green Mountain	110	.....	.....	.....	.....	100	43.0	31	25.8
var. *mutica*	32	.....	.....	134	11.9	70	18.5	41	14.6
var. *obtusata*	33	128	7.0	99	11.0	88	14.7	44	9.0
var. *pugnax*	65	.....	.....	126	26.2	50	2.0	8	12.5
var. *setosa*	14	127	7.0	97	7.2	86	18.6	14	0.
var. Sparrowbill	102	.....	.....	.....	.....	102	23.5	.....	.....
var. Sparrowbill	111	.....	.....	.....	.....	113	28.3	55	14.5
var. Storm King	112	.....	.....	.....	.....	86	6.9	33	15.1
var. *tartarica*	5	151	6.6	104	6.7	89	19.1	.....	.....
var. *tartarica*	34	.....	.....	171	20.4	.....	.....	.....	.....
var. Tartar King	113	.....	.....	.....	.....	80	22.5	60	16.6
var. *tristis*	40	129	19.3	154	16.9	40	42.5	17	0.
var. White Tartar	106	.....	.....	.....	.....	80	35.0	.....	.....
var. White Tartar	174	.....	.....	.....	.....	.....	.....	41	9.7
Avena sterilis L.	27	116	22.4	132	0.	22	50.0	.....	.....
Avena sterilis L.	28	.....	.....	122	0.	56	0.	7	0.
Avena sterilis L.—									
var. Burt	67	179	1.6	206	0.	70	0.	87	0.
var. Burt[1]	74	.....	.....	90	0.	100	14.0	121	6.6
var. Burt	175	.....	.....	.....	.....	.....	.....	36	0.
var. Burt	253	.....	.....	.....	.....	.....	.....	202	1.9

TABLE 4.—GENERAL SUMMARY OF RESULTS WITH *Ustilago Levis* (K. & S.) MAGN. (*Continued*)

Species and Variety	Seed No.	1915		1916		1918		1919	
		Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.	Total No. Plants	Per cent Inf.
Avena sterilis L.									
var. Early Ripe[2]	75	124	2.4	105	0.	70	7.1	148	6.0
var. Fulghum	129	.....	.....	.....	.....	69	1.4	204	0.4
var. Fulghum	257	.....	.....	.....	.....	.....	.....	218	1.3
var. Italian Rustproof	260	.....	.....	.....	.....	.....	.....	65	4.6
var. *ludoviciana*	80	.....	.....	97	9.3	96	20.8	.....	.....
var. *ludoviciana*	176	.....	.....	.....	.....	.....	.....	23	0.
var. nigra	130	.....	.....	.....	.....	.....	.....	37	0.
var. Red Rustproof	98	226	26.1	.....	.....	78	56.4	.....	.....
var. Red Rustproof	131	.....	.....	.....	.....	.....	.....	24	16.6
var. Selection	132	.....	.....	.....	.....	120	6.6	.....	.....
var. Turkish Rustproof	267	.....	.....	.....	.....	.....	.....	54	0.
var. Turkish Rustproof	268	.....	.....	.....	.....	.....	.....	50	4.0
Avena strigosa Schreb.	29	60	0.	117	0.	100	0.	260	0.
Avena strigosa Schreb.[3]	76	.....	.....	.....	.....	100	0.	168	0.
Avena strigosa Schreb.	133	.....	.....	.....	.....	100	0.	105	0.

[1]This variety does not resemble very closely the other Burt strains.
[2]This variety resembles very closely Burt (74).
[3]This strain was received under the name of *Avena barbata.*

Results for 1914.—In one experiment eleven varieties belonging to seven species of Avena were inoculated, after pre-soaking the seed for four to five hours, with the dry spores of *Ustilago avenae*. The seed was planted very late, May 1. The number of plants that developed in some varieties was very small and, in consequence, the results are not at all conclusive. However, three varieties of *Avena sativa orientalis* L., one variety of *Avena nuda* L. and Early Champion, a variety of *Avena sativa* L., gave relatively high percentages of infection. One strain of Burt and Early Ripe, varieties of *Avena sterilis* L., proved free from smut. Further, no infection occurred with *Avena brevis* Roth. and *Avena strigosa* Schreb.

In a second experiment eighteen varieties of commonly cultivated oats were tested. Most of these belonged to *Avena sativa* L. and a few to *Avena sativa orientalis* L.; Early Ripe and Burt, varieties of *Avena sterilis* L., were included. The dry seed was inoculated with the dry spores.

Infection occurred in every variety; it amounted to 2.5 per cent in Burt (67), and 7.5 per cent in Early Ripe (75). In practically all the other varieties the percentage of infection was from about twenty to more than sixty per cent.

Results for 1915.—In this year only *Ustilago levis* was used. The dry seed of twenty-three varieties were inoculated with the dry spores. In nearly every case the seed was divided into two lots, one of which was planted April 2 and the other April 24. In the general table the combined results of these two plantings are given. *Avena brevis* Roth., *Avena strigosa* Schreb. and a few varieties of *Avena sativa* L. gave negative results. A number of other varieties including Burt and Early Ripe were only slightly infected. *Avena sativa* L. var. *Early Champion* and *Avena nuda* L. var. *elegantissima* gave relatively high percentages of infection.

Results for 1916.—Forty-three strains or varieties belonging to nine species were inoculated with the spores of *Ustilago avenae;* thirty-five of these were also inoculated with the spores of *Ustilago levis*. Several gave negative results with both smuts, namely, *Avena brevis* Roth. (two strains), *Avena sativa* L. var. *nigra* (70), *Avena sterilis* L. (28), *Avena sterilis* L. var. *Burt* (67) and *Avena strigosa* Schreb. A few others were infected by one smut but not by the other. Varieties of *Avena nuda* L. were severely infected with *Ustilago avenae* but were not tested with *Ustilago levis*. In the other varieties the percentages of infection varied greatly, some more severely with the loose smut, others more severely with the covered smut.

Results for 1917.—During this season only *Ustilago avenae*

was used in the experiments. Seed of twenty-seven strains and varieties were inoculated with the dry spores. One set of seed was planted March 24 and a second set on April 12. In the general table the results for both planting dates are combined.

No infection occurred in *Avena brevis* Roth., *Avena sativa* L. var. *mutica* (45) and *nigra* (12), *Avena sterilis* L. var. *Burt* (67) and *Early Ripe* (75), nor *Avena strigosa* Schreb. The varieties of *Avena nuda* L. gave very high infection percentages—68.7 to 98.1.

Results for 1918.—Ninety-nine strains and varieties belonging to eight species were inoculated with spores of *Ustilago avenae* and ninety-six with the spores of *Ustilago levis*. The same strains and varieties were inoculated in both series with a few exceptions.

As in previous years, *Avena brevis* Roth. and *Avena strigosa* Schreb. gave negative results; *Avena sativa* L. var. *Black Mesdag* (117) and *nigra* (70) also proved free. No smutted plants of *Avena fatua* were observed, but the total number of plants was very small in both series. *Avena sativa* var. *Black Diamond* (116), *C. I. 606* (127), *mutica* (45), *Avena sterilis* var. *Burt* (67) and *Fulghum* (129) gave low infection percentages with both smuts.

Varieties of *Avena nuda* L. again proved very susceptible to both smuts. Other varieties highly susceptible to *Ustilago avenae* were *Avena sativa orientalis* L. var. *Garton's Black* (88), *Avena sativa* var. *Culberson* (120), *Great Dakota* (89), *mutica* (52), and *White Queen* (103). Varieties badly infected with *Ustilago levis* were *Avena sativa orientalis* var. *Garton 748* (109), *Avena sativa* var. *American Banner* (82), *Canadian* (119), *Avena sterilis* var. *Red Rustproof* (98).

Results for 1919.—One hundred and five strains and varieties belonging to nine species were used, both smuts being employed for inoculating different sets of seed. In both cases dry seed was inoculated with dry spores. A large number of rows of some of the varieties that proved free from smut in previous years were planted in order to give these a full test.

Complete freedom from smut was observed in the case of *Avena brevis* (77 and 134), *Avena strigosa* (29 and 133), *Avena ludoviciana* (176), *Avena sativa* var. *aurea* (7), *Black Mesdag* (117), *Krausei* (9), *Monarch* (161), *mutica* (54), *nigra* (70), *Avena sterilis* var. *Burt* (175), *Fulghum* (129), *nigra* (130), *Turkish Rustproof* (267, 268). In addition very low infection occurred in several cases, notably *Avena sativa* var. *mutica* (45 and 57), *Avena sterilis* var. *Burt* (67 and 253) and *Fulghum* (257). Some of these were tested for the first time. Others had been tested one or more years previously.

On looking over the records for all the years the following facts may be specially noted:

1. Altogether one hundred and fifty-four strains and varieties belonging to seven species of *Avena* were inoculated with the spores of *Ustilago avenae*. These strains and varieties were distributed as follows: *Avena brevis* (three), *A. fatua* (three), *A. nuda* (four), *A. sativa* (ninety-nine), *A. sativa orientalis* (twenty-four), *A. sterilis* (eighteen) and *A. strigosa* (three).

2. One hundred and forty-six strains and varieties belonging to the same species were inoculated with the spores of *Ustilago levis*. These were distributed as follows: *Avena brevis* (three), *A. fatua* (three), *A. nuda* (four), *A. sativa* (ninety-three), *A. sativa orientalis* (twenty-two), *A. sterilis* (eighteen) and *A. strigosa* (three).

3. *Avena brevis* Roth. and *A. strigosa* Schreb. proved entirely free from both smuts. *Avena brevis* Roth. (1) was used with *Ustilago avenae* four years and *Ustilago levis* two years; *Avena brevis* (77) with *Ustilago avenae* four years and *Ustilago levis* two years; *Avena brevis* (134) two years with both smuts. *Avena strigosa* Schreb. (29) was tested with *Ustilago avenae* five years and with *Ustilago levis* four years; *A strigosa* (133) was tested two years with both smuts; *A. strigosa* (76) was tested with *Ustilago avenae* four years and with *Ustilago levis* two years.

4. *Avena sativa* L. var. *nigra* (70) and *A. sativa* var. *Black Mesdag* (117) also proved entirely free from both smuts. The first variety was tested three different years with both *Ustilago avenae* and *Ustilago levis;* Black Mesdag was used two years with both smuts. These two are very similar if not identical; the first was received from Doctor Bubak and the second from Doctor Etheridge.

5. Most of the varieties of *Avena sterilis* L. gave very low percentages of infection. Four different strains of Burt oats were tested. Three of these were very slightly infected, the other relatively high. It is doubtful if this strain is really a Burt Oats; it does not resemble very closely the other strains. This is true of the results with both smuts. The *Early Ripe* strain used also proved somewhat susceptible. *Fulghum, Italian Rustproof, nigra, Selection* and *Turkish Rustproof* either gave negative results or very low percentages of infection. Some of these were tested only one year. The strains of *Red Rustproof* proved quite susceptible.

6. The varieties of *Avena nuda* L. were highly susceptible. Generally from sixty to one hundred per cent of the plants were infected with both smuts.

7. There was greater or less variation in the amount of infection

in the varieties of *Avena sativa* L. and *A. sativa orientalis* L. from year to year. Some years a particular variety would prove free from one or both smuts and in other years become more or less infected. One year's tests are not at all conclusive as to the resistance of a variety. When, however, a variety remains free for a succession of years there is good evidence for a high degree of resistance.

8. No apparent differences in the infection capacity of the two species of smuts may be noted. In a given year a variety may be infected slightly or not at all by one smut and severely by the other. The relations may be reversed the following year. It is specially striking that those forms, like *A. brevis, A. strigosa, A. sativa* var. *nigra* and *Black Mesdag* have proved free from both smuts, that most varieties of *A. sterilis* are only slightly infected by both smuts and that the *A. nuda* group is highly susceptible to both.

GENERAL SUMMARY

In this paper the results of inoculation experiments with powdery mildew, crown rust, loose and covered smuts of oats are reported.

Ninety-eight varieties and strains belonging to fourteen species of Avena have been tested with the powdery mildew. Negative results were obtained with only two—*Avena bromoides* and *A. sempervirens. Avena brevis* (four strains), *A. fatua* (five strains and varieties), *A. nuda* (three strains and varieties), *A. planiculmis, A. pratensis, A. purpurea, A. sativa* (fifty-one strains and varieties), *A. sativa orientalis* (fourteen strains and varieties), *A. sterilis* (fifteen strains and varieties) and *A. sulcata* gave positive results. In most of these cases complete infection occurred on every inoculated plant. Successful infection of *Arrhenatherum elatius* was also obtained in a few cases. *Holcus lanatus, Lolium multiflorum, Hordeum vulgare* and *Triticum vulgare* gave negative results. Especially striking is the vigorous infection which occurs on all cultivated varieties of oats.

Including Brentzel's results one hundred and thirty-two strains and varieties belonging to seven species were tested with the crown rust of oats. These were distributed as follows: *Avena brevis* (five), *A. fatua* (six), *A. nuda* (four), *A. sativa* (seventy-one), *A. sativa orientalis* (twenty-two), *A. sterilis* (twenty-one) and *A. strigosa* (three). Of these ninety-two were fully infected in every experiment. Uredo pustules, in greater or less number, broke open on every inoculated leaf. In thirty-four additional varieties infection occurred on seventy-five to ninety-nine per cent of the plants inoculated, infection failing on one or more plants in an individual experiment or, rarely, negative results being obtained on all plants in one series. Five varie-

ties had fifty to seventy-four per cent of the inoculated plants infected. The remaining variety, a strain of *Avena brevis,* gave forty-two per cent infection, eleven out of twenty-six inoculated plants being infected. The period of incubation, the number of pustules, their size, shape, etc., were essentially the same on all the varieties. One variety, *Avena sativa* var. *trisperma,* frequently showed a slightly longer incubation period and the development of fewer pustules. So far as seedling inoculation experiments are concerned one is impressed with the very great susceptibility of practically all oat varieties tested to the crown rust.

One hundred and fifty-four varieties and strains belonging to seven species were tested with loose smut during the seasons of 1914, 1916, 1917, 1918 and 1919. Most of these have been tested more than one season. The following gave consistently negative results—*Avena brevis, Avena sativa* var. *Black Mesdag* (117) and *nigra* (70) and *A. strigosa.* Most of the varieties of *A. sterilis,* especially Burt, Early Ripe, Fulghum and Selection, have given very low percentages of infection. In any one season several varieties have given negative results but these are not considered significant. When, however, the same variety for two or more years gives negative results or consistently low percentages of infection it must possess great resistance to the parasite. The *Avena nuda* group proved highly susceptible.

One hundred and forty-six varieties and strains were treated with covered smut during 1915, 1916, 1918 and 1919. In general the different species and varieties reacted to this smut in the same way as they did to the loose smut. Varieties highly resistant or susceptible to one smut behaved similarly towards the other.

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