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Department of Botany.

Smuts and Rusts of Grains in Idaho, and the Most Approved Methods of Dealing With Them.

By L. F. HENDERSON.

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BULLETINS.

The regular bulletins of the Station are sent free to all who request them. Bulletins issued since the close of the fiscal year, June 30, 1897.

11. Smuts and Rusts of Grain in Idaho, and the Most Approved Methods of Dealing With Them.

SMUTS AND RUSTS OF GRAINS IN IDAHO, AND THE MOST APPROVED METHODS OF DEALING WITH THEM.

The knowledge of the injury inflicted upon the farmer by rusts and smuts is probably as old as the cultivation of the cereals by man. That the mischief was well understood by the Greeks and Romans is evident, since they had a God, Robigus, amongst the Romans, whose special province it was to watch over the crops and "avert the mildew." At the present time, these diseases are common in almost every clime and country, being especially prevalent in many of the states of our Union. In some sections of some of the southern states they have actually ceased attempting to raise grain, so badly affected is it by smut or rust. In our own state of Idaho doubtless the amount of grain lost by these causes is greater than many of the farmers realize. There are many who still cling to the old notion about smuts and rusts,—that they are special dispensations of Providence, or that they are the natural and spontaneous products of the soil stimulated by excessive moisture or manure. A few minutes' observation with a microscope of only moderate magnification would show to them at once that they are PLANTS, living in the tissues of their hosts, and passing through their various cycles of existence as do other plants,—their virulence often minimized or exaggerated by their special environment, such as excessive moisture in ground or atmosphere, unrotted manure, improper care of the ground and the previous year's stubble,—but in no wise a special creation or product of the soil. I think there are but few farmers of any intelligence that still hold to these ideas long ago exploded; yet, while this is the case, there are thousands, who knowing the causes and effects of these

diseases, do nothing to prevent the losses in yield and quality of grain consequent upon their attacks. These losses in the United States, to say nothing of foreign countries, are simply enormous, and would seem like fairy tales, were they not substantiated by scientific proof. These smuts and rusts are of various kinds or species, and the appalling losses sustained from the different species can be seen from the following brief list, taken from the records of the Department at Washington, or from those of the various stations:

In a few districts of the Southern States,.....total loss.
From Stinking Smut, at times.....50 to 75 per cent loss.
From Loose Smut of Wheat, at times,....10 to 15 per cent loss.
From Loose Smut of Oats, ...6.5 to 15 per cent loss.
From Loose Smut of Oats annually in U. S.,...over $18,000,000.
From Rust of Wheat annually in U. S , ...over 4,000,000.
Combined Losses from these diseases in U. S.,..over 50,000,000.

Now the greater part of all this loss might be prevented if the raisers of grain would unite against these common enemies. Many, if not the most, of the farmers throughout the United States have already arrayed themselves in continuous battle along these liner, and as a result, on those farms where the latest and most approved scientific methods have been inaugurated, the losses have been reduced to a minimum.

In order that the farmers of our state may have a fair comprehension of these diseases and the methods used to combat them, it will be my aim to write simply and shortly of the life history of each, and the best method or methods of prevention. In all that follows, but little claim is made of originality. The only experiments made on these diseases at our station have been with the Bunt or Stinking Smut, and consequently I shall speak of this pest first.

BUNT OR STINKING SMUT.

(Tilletia levis, Kuhn. and T. tritici, (Bk) Winter.)

If one should pass along a field of wheat affected by this disease about the time of harvest, he would notice a very disagreeable oder, provided the wind were blowing from the grain. This was especially noticable on some of the station plots a few

years since. If he were of an investigating frame of mind and was not already acquainted with the cause of the peculiar odor, he would likely direct his steps towards and amongst the wheat.

Fig. 1.

Fig. 2

Fig. 1 Head of beardless wheat affected with smut.
Fig. 2. Head of bearded wheat affected with smut.
Swingle, Year Book for 1894, Department of Agriculture.

Nothing would there especially attract his attention, except he might notice that many of the heads of wheat were of a lighter, faded color, while the chaff and beards would present a more gaping look, and the berries a plumper appearance than those of the ordinary heads. If he should pick out, or attempt to pick out, one of the berries, more than likely it would crumble in his fingers, and the whole interior of the seed would be found to be filled with a black-brown powder, emitting a foetid smell, and having an unctuous feeling.

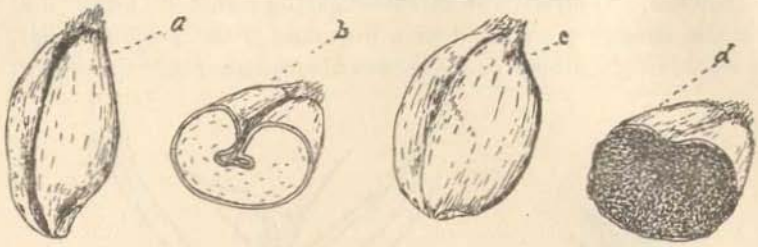

Fig. 3.

Fig 3. Sketches showing characteristics of sound and smutted grains of wheat: (a) a perfect grain showing the deep longitudinal crease of groove; (b) a similar grain cut across showing general contour and appearance of cut surface; (c) a grain affected by the smut showing the plump or puffed appearance as compared to the normal kernel; (d) a diseased grain such as (c) cut across, showing the hull or covering of the grain filled with the smut spore.—Bolley.

If he had a microscope of moderate power in his possession, placing a little of this powder upon a slide and then viewing it through the microscope, he would find it composed of an innumerable quantity of small dark brown, roundish bodies with here and there a few fragments of some dark, disintegrated stuff. These bodies are the spores of the fungus, destined to carry it over the winter, or over several winters, while the small, dark fragments are the remains of the stalks, or hyphae, that bore the growing spores. This fungus is of two kinds or species, one with perfectly smooth spores (T. levis) and the other (T. tritici (Bk.) Winter,) with spores whose surface is marked by net-like ridges. Both kinds have been found at out station by the writer, though this is not a matter of any importance to the farmer, as both yield to the same treatment.

HOW SMUT GROWS.

A remarkable thing about the smuts is that they are not contagious diseases,—this is communicated from one plant to another while growing in the field. In this characteristic the smuts differ radically from the rusts, as will be shown when we come to speak of the latter fungi. How then, and at what point in the life of the wheat plant does the smut attack the growing grain? If the seed of wheat, which has either at the time of threshing or afterwards been brought in contact with smut-

spores be examined, it will be found to be more or less covered with the little, adhering spheres. It has been found by experiment that the same conditions that are most essential for the germination of the wheat-grains are also most essential for the germination of the spores of smut. Warmth and moisture are as necessary for the one as for the other, and even a fertilizer that is directly beneficial to the wheat plant is beneficial to the smut through the stimulus to the wheat and a consequent better support to the fungus. These facts account for the exploded idea that warmth with excessive moisture, or an undue amount of a fertilizer, or improperly rotted manure, are the DIRECT PRODUCERS of smut and rust. They undoubtedly aggravate the disease, but in no wise cause it.

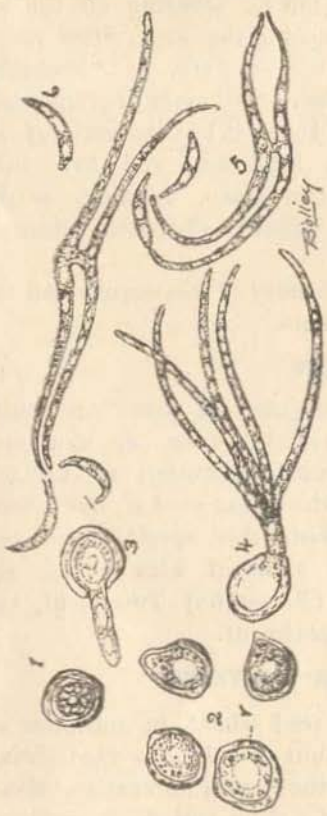

Fig. 4.

Fig. 4. Drawing illustrating the germination of stinking smut of wheat, Tilletia levis Kuhm. (1) represents a high magnification of a single mature spore. (2) four spores starting to germinate on the second day after moisture is applied. (3), (4), (5) and (6) represent different stages occuring inside of four days. The figures appear about nine hundred times as large in each direction as the originals from which they were drawn, due to magnification.—Bolley.

Now plant the infected grains of wheat, and what is the result? As soon as the grain has germinated and begins to send up its little plumule, or "sprout," the grains of smut germinate, and immediately attack the young wheat plant somewhere below the first joint. This is done by sending out a little tube which penetrates the tender skin of the young wheat, and immediately begins to expand within the stem, mounting upwards, as a vine climbs a

wall, towards and into the head. It has been proven that if infection does not take place while the wheat plant is in this very immature condition it cannot take place at all, for the hardening of the epidermis and outer tissue of stalk soon shut off all ingress to the smut-tubes. *Bolley has shown us that the growing parasite injuries the wheat-plant, not only by absorbing and living on its juices, but by shutting off the air intended for the host by filling in most of the air-cavities found in the stem of the plant just below the stomata, or "breathing pores," through which air is admitted. Still mounting upwards, the smut-filaments enter the ovary before it has become at all ripened, that is before the starch is hardened, and here they absorb and live upon the vitals of the grain, forming, as the starch is used up, the innumerable quantity of spores before alluded to.

This in a few words is the life-history of this smut, and as far as known that of most of the others.

PREVENTIONS.

It is evident from what has been just said, that "An ounce of prevention is worth"—more than all the CURE we can conceive of. In fact all our exertions must be directed at KILLING OR REMOVING the smut-spores from the wheat seed if our efforts are to be crowned with success. With this special smut two methods have been most tried and stamped with public approval. One is Copper Sulphate (Bluestone) Treatment, the other is the Jensen or Hot Water Treatment.

COPPER SULPHATE TREATMENT.

This consists in immersing the seed wheat in solutions of copper sulphate and water, the amount of sulphate used being generally in inverse proportion to the time if immersion. Some prefer great strength of solution and a short period of immersion, while more, I believe, prefer less strength and a longer period. *Swingle, who has had a great deal of experience in these matters, recommends the following:

"Immerse the seed wheat 12 hours in a solution made by

* Bulletin No. 27 North Dakota Station, 1897.

disolving one pound of commercial copper sulphate in 24 gallons of water, and then putting the seed for 5 to 10 minutes into lime-water made by slaking 1 pound of good lime to 10 gallons of water.

The treatment is cheap, easily applied and very effective. The wheat does not grow quite so well as when treated with hot water, but the difference is inconsiderable."

Bolley recommends the following treatment:

"Pile the wheat to be treated upon the floor or upon a canvass and thoroughly sprinkle or spray on a solution of copper sulphate ($Cu\ S\ O_4$) at the rate of one pound of sulphate to 4 gallons of water, while the grain is being constantly shoveled over so that every grain becomes wet over its entire surface. Do not use any more of the solution than necessary to do this; an excess is injurious to the seed."

JENSEN OR HOT WATER TREATMENT.

About ten years ago J. L. Jensen, a Danish investigator, discovered that seed badly infected with stinking smut could be effectually cleaned by bathing the seed wheat in hot water at a certain temperature and for a certain length of time. He found though the wheat would germinate when subjected to varying degrees of heated water and to varying times of immersion, within certain limits, the best results were obtained when the temperature of the water was about 132 degrees Fahrenheit, and the time if immersion not over 10 to 15 minutes. In no case should the water be allowed to fall to less than 130 degrees, and in no case rise to more than 135 degrees. If the temperature of the water be less than 130 degrees, the spores of the smut will not be killed; while if the temperature rise above 135 degrees, the germinating power of the wheat will be more or less reduced. In the year-book of the Department of Agriculture for the year 1897, there is an article by Mr. Walter T. Swindle entitled, "The Grain Smuts: Their Cause and Their Prevention." In this article there is so admirable a plan for treating wheat affected with stinking smut by the hot water treatment that I shall probably be pardoned for reproducing this part of the

* Grain Smuts; Their Cause and Prevention, U. S. Dept. of Agr. for '94.

article in its entirety. I quote pages 415-417:

"Provide two large vessels, preferably holding at least 20 gallons. Two wash kettles, soap kettles, wash boilers, or even barrels, will do. One of the vessels should contain warm water, say at 110° to 120° F., and the other scalding water, at 132° to 133° F. The first is for the purpose of warming the seed preparatory to dipping it into the second. Unless this precaution is taken it will be difficult to keep the water in the second vessel at the proper temperature. A pail of cold water should be at hand, and it is also necessary to have a kettle filled with boiling water from which to add from time to time to keep the temperature right. Where kettles are used a very small fire should be kept under the kettle of scalding water. The seed which is to be treated must be placed, half a bushel or more at a time, in a closed vessel that will allow free entrance and exit of water on all sides. For this purpose there can be used a bushel basket made of heavy wire, inside of which is spread wire netting, say 12 meshes to the inch; or an iron frame can be made at a trifling cost over which the wire netting can be stretched. This will allow the water to pass freely and yet prevent the passage of the seed. A sack made of loosely woven material, as gunny sack, can be used instead of the wire basket. A perforated tin vessel is in some respects preferable to any of the above. In treating stinking smut of wheat, the grain should first be thrown into a vessel filled with cold water; then, after stirring well, skim off the smutted grains that float on top and put the grain into the basket or other vessel for treatment with hot water. This skimming is entirely unnecessary with other grains, and even with wheat when affected only by the loose smut. Now dip the basket of seed in the first vessel, containing water at 110° to 120° F; after a moment lift it, and when the water has for the most part escaped plunge it into the water again, repeating the operation several times. The object of the lifting and plunging, to which should be added also a rotary motion, is to bring every grain in contact with the hot water. Less than a minute is required for this preparatory treatment, after which plunge the basket of seed into the second vessel, containing water at 132° to

133 F. If the thermometer indicates that the temperature of the water is falling, pour in hot water from the kettle of boiling water until the right degree is attained. If the temperature should rise higher than 133, add a little cold water. In all cases the water should be well stirred whenever any of a different temperature is added. The basket of seed should very shortly after its immersion be lifted and drained, and then plunged and agitated in the manner described above. This operation should be repeated six or eight times during the immersion, which should be continued ten minutes. In this way every portion of the seed will be subjected to the action of the scalding water. In practice it will be found best to have a man or boy devote his whole time to keeping the temperature at the right point, adding a little hot water if it falls below 132 and a little cold water if it gets above 133 F. Another man should handle the grain and immerse and drain the portions being treated as directed above. After removing the grain from the scalding water, spread on a clean floor or piece of canvass to dry. The layer of grain should not be over 3 inches thick. If it can not be spread out at once, dip in cold water and set to one side until it can be attended to. It dries better if spread while still hot. Another portion of grain can then be treated, and so on until all the seed has been disinfected. Directions for drying the seed will be given further on.

The important precautions to be taken are as follows:

(1) Maintain the proper temperature of the water (132 or 133 F.), in no case allowing it to rise higher than 135 or fall below 130; (2) see that the volume of scalding water is much greater (at least six or eight times) than that of the seed treated at any one time; (3) never fill the basket or sack containing the seed entirely full, but always leave room for the grain to move about freely; (4) leave the seed in the second vessel of water ten minutes.

When steam is available, it can be conducted into the second vessel (containing the scalding water) by a pipe provided with a stopcock, and this answers better than any other method for heating the water and for elevating the temperature from

time to time. A good arrangement for hot-water treatments is shown in figure 99.

A pole is provided having a large hole at one end, which passes over a small peg in the top of the first post. This should allow the pole to move both up and down and sidewise. By swinging the pole around the basket can be filled at the bin, immersed a moment in the vessel No. 1, and then swing over to vessel No. 2, where the grain is treated ten minutes. Every minute or so the basket must be raised entirely out of the water allowed to drain. The pole can be supported on a peg or fork in the second post while the basket is draining. Finally, the pole is lifted entirely over the second post and the grain is spread out to dry. Of course this arrangement is necessary only when large amounts of seed are to be treated. For small amounts a tub of warm water and a common wash boiler on a cook stove for the scalding water will answer every purpose.

There are many possible modifications of the hot-water treatment that are more easily used than the one here given, but whenever they have been tested on a large scale they have proven uniformly less successful to preventing smut than the method here given, and do not give as great an increase in yield. They are moreover, not nearly as convenient as the potassium sulphide or bluestone and lime methods."

Results of Treatments for Stinking Smut Conducted at the Idaho Experiment Station at Moscow, Idaho, for the Years 1895–6–7.

This subject has received enough attention from the Agricultural Department of the Idaho Experiment Station to warrant publication. The treatments used were mainly the Copper Sulphate and Hot Water. Although these treatments have been extremely limited in number and deficient in many details, they are sufficiently valuable in results to serve as an object lesson to those who wish light on these matters. These experiments have been carried through by the present Agriculturist and by his predecessor, and the results are given on their authority.

SMUT TREATMENT FOR 1895-6.

A smooth variety of wheat (Mc. Cracken) of the '95 crop had 75 per cent of the wheat smutty. A quantity was washed in a tub, and all the floating grains removed. Smut from the broken grains finally sank and coated the unaffected grains, which were removed and dried. The grain was then treated as shown in the table. It was sown Oct. 16-20, 1895, two bushels to the acre, in single rows 28 feet long and 2 feet apart running north and south. During July 1896, 10 feet of each row was cut for samples and 15 feet for weight, leaving 3 feet to stand.

The first column gives the number of the row.

The second column gives the treatment, $CuSO_4$ being the chemical formula for copper sulphate.

The third column shows the strength of the treatment, i. e. the number of gallons of water to each pound of copper sulphate.

The fourth column shows the time of treatment in minutes.

The fifth column shows the per cent of smutted grain.

The sixth column shows the pounds of wheat obtained from 10 feet of row, which equals 1-2178 acre.

The seventh column shows the pounds of straw obtained from each 15 feet of row, which equals 1-1452 acre.

1	$CuSO_4$	1-1	5	7.9	1 11-16	6 5-16
2	"	1-1	10	10.8	1 10-16	5 14-16
3	"	1-1	15	5.5	1 11-16	4 13-16
4	"	1-1	30	5.9	1 13-16	4 11-16
5	"	1-1	60	6 5	2 4-16	4 12 16
6	Check. Nothing			88 1	6-16	4 2-16
7	$CuSO_4$	1-2	5	12 7	1 5-16	4 3-16
8	"	1-2	10	8 3	2 4-16	4 12-16
9	"	1-2	15	6 2	1 4-16	4 4 16
10	"	1-2	30	3 4	2 7-16	4 7-16
11	"	1-2	60	2 9	1 12-16	5 4-16
12	Check, Nothing.			85.4	8-16	3 8-16
13	$CuSO_4$	1-4	5	12.7	2 4-16	5 12-16
14	"	1-4	10	8.9	2 2-16	5 6-16
15	"	1-4	15	7.2	1 15-16	4 9-16
16	"	1-4	30	7.4	2 3-16	5 5-16
17	"	1-4	60	8.5	2 4-16	5 12-16
18	Check, Nothing.			87.0	4-16	3 12-16
19	$CuSO_4$	1-8	5	12.9	2 1-16	5 15 16
20	"	1-8	10	13.5	1 12-16	4 12-16
21	"	1 8	15	10.5	1 12-16	4 7 16
22	"	1-8	30	8.3	1 11-16	4 13-16
23	"	1-8	60	8.6	1 12 16	4 12-16
24	Check, Nothing.			82.9	8-16	3 8-16
25	$CuSO_4$	1-16	5	36.0	1 12-16	5 4-16
26	"	1 16	10	28.9	1 11-16	4 13 16
27	"	1-16	15	21.4	1 12 16	5 4-16
28	"	1-16	30	14.7	1 13-16	4 11-16
29	"	1-16	60	17.8	2	5
30	Check. Nothing.			84.9	7-16	3 9-16
31	$CuSO_4$	1-32	5	49.4	1 8-16	5
32	"	1-32	10	51.8	1 4-16	4 12 16
33	"	1-32	15	46.1	1 5-16	5 3-16
34	"	1-32	30	45.7	1 6-16	5 2-16
35	"	1-32	60	39.8	11-16	5 5-16
36	Check, Nothing.			86.4	6-16	3 10 16
37	Hot Water.		5	22.8	2 2-16	4 14-16
38	"	"	10	7.2	1 15-16	5 1-16
30	"	"	15	2.2	2 3 16	4 13-16
40	"	"	30	.3	2 2-16	4 13 16
41	"	"	60	.0	1 2-16	2 6-16

DEDUCTIONS.

1. The grain was well smutted by the sinking of the spores and by their adhersion to the grains of wheat in the sinking of the latter.

2. The untreated grain was badly smutted, averaging almost 86 per cent.

3. The average of wheat obtained from the untreated plots was 65-100 to each 10 feet, or only about 14 bushels to the acre.

4. The best destruction of the smut in the $Cu\,S\,O_4$ column was obtained in Plat 11, by a treatment of the grain for one hour to a solution whose strength was one pound of copper sulphate to 2 gallons of water; but at the same time the germinating power of the seed was impaired, and the amount of wheat produced fell off, though not so markedly as would be expected.

5. The greatest yield of wheat was obtained, under the $Cu\,S\,O_4$ treatment, in plats 13–17, (excepting the phenominal and inexplicable yield in plot 5), averaging about $2\frac{1}{4}$ pounds of wheat to the 10 feet of wheat, or about 77.1 bushels to the acre.

When we come to the Hot Water treatment, however, we see even more marked results. No very good means was adopted of keeping the water at an even temperature, so it varied between 130° and 135°,—both extremes though within the danger limit.

Here the natural deductions are:

1. That the hot water treatment is more effective than the "bluestone," in the killing of the smut, the per cent of smut falling as low as .3 per cent or even zero.

2. That the germination of the wheat and as a rather natural consequence, the yield of wheat was not sensibly impaired till the time of immersion passed thirty minutes, when the yields of wheat and of straw fell off noticeably.

3. That a 5 minutes immersion killed off less than three-fourths of the smut spores.

Too much credence must not, however, be given to one set of experiments; while on the other hand "he who runs may read" that the bluestone and hot water treatments are both very effective in the supression of stinking smut or bunt.

EXPERIMENTS CONDUCTED FOR SMUT IN 1896-7.

Little club wheat was obtained from a warehouse in Moscow, washed as far as possible from smut, and then infected with smut raised in 1896 and broken into a fine powder. The wheat was then treated with the preventive and dried on clean paper or in clean boxes before being sown. It was sown in 62 rows, each 40 feet long and 20 inches apart. 2 9-16 ounces of wheat was sown to a row, equaling about 2,000 grains, and in the proportion of $1\frac{3}{4}$ bushels to the acre.

No.	Preventive or Reagent.	Strength Lb. to Gals.	Time Min.	Per Cent. Stand May 1	Per Cent Smut.
1	$CuSO^4$	1 - 1	5	95	.5
2	"	1 - 1	10	90	.2
3	"	1 - 1	15	90	.2
4	"	1 - 1	30	90	.1
5	"	1 - 1	60	90	.0
6	"	1 - 1	360	90	.0
7	"	1 - 1	720	90	0
8	Check			100	88.7
9	$CuSO^4$	1 - 2	5	98	.9
0	"	1 - 2	10	95	.1
11	"	1 - 2	15	95	.9
12	"	1 - 2	30	90	1.0
13	"	1 - 2	60	95	.5
14	"	1 - 2	360	95	.5
15	"	1 - 2	720	80	.3
16	Check			100	89.2
17	$CuSO^4$	1 - 4	5	100	5.1
18	"	1 - 4	10	100	5.2
19	"	1 - 4	15	100	4.5
20	"	1 - 4	30	100	1.7
21	"	1 - 4	60	100	1.9
22	"	1 - 4	360	100	1.7
23	"	1 - 4	720	98	0.1
24	Check			100	87.6
25	$CuSO^4$	1 - 8	5	100	12.0
26	"	1 - 8	10	100	8.1
27	"	1 - 8	15	100	5.5
28	"	1 - 8	30	100	2.1
29	"	1 - 8	60	100	2.7
30	"	1 - 8	360	100	2.0
31	"	1 - 8	720	100	1.4
32	Check			100	88.9

33	$CuSO^4$	1 - 16	5	100	15.1
34	"	1 - 16	10	100	10.2
35	"	1 - 16	15	100	8.2
36	"	1 - 16	30	100	7.7
37	"	1 - 16	60	100	6 8
38	"	1 - 16	360	100	8.0
39	"	1 - 16	720	100	2.8
40	Check			100	89 7
41	$CuSO^4$	1 - 32	5	100	16.6
42	"	1 - 32	10	100	14.7
43	"	1 - 32	15	100	14.9
44	"	1 - 32	30	100	10.9
45	"	1 - 32	60	100	9.6
46	"	1 - 32	360	100	8.7
47	"	1 - 32	720	100	4 1
48	Check			100	90.1
49	Uncleaned original wheat			100	86 2
50	" " "			100	87.3
51	" " "			100	88.5
52	Thoroughly washed by Hydrant			100	33.7
53	Original uncleaned			100	41.1
54	Hot Water	132 - 136 F	5	98	.1
55	" "	132 - 138 F	10	60	.0
56	" "	132 - 138 F	15	10	Grain all kil'ed
57	" "	132 - 138 F	30	1	"
58	" "	132 - 138 F	60	0	"
59	" "	132 - 138 F	120	0	"
60	Infected as for $CuSO^4$ and then Soaked		30	100	49 2
61	Soaked		60	100	50.7
62	Washed under hydrant and stirred			100	52 3

Owing to changes in the Station staff, no records of the yield in either grain or straw were kept in this last set of experiments. It is only interesting therefore in showing the wonderful effect of the copper sulphate treatment in the suppression of smut. The relative per cent stands are given as showing that large yields of straw and grain could be expected. I am likewise informed by various laborers on the station that the yields of both wheat and straw were unusually heavy, the wheat-crop of the whole Palouse country being a very large one that year.

Before leaving this form of smut I may add that *Bolley

*Bulletin No. 27 North Dakota Ex. Station for 1897, P. 139 et al.

has found that Corrosive Sublimate ($HgCl_2$) is a very effective fungicide when used in the proportion of 1 lb. to 50 gallons of water, or 2½ parts to the 1,000. The pile of grain should be sprayed with just enough of the liquid to wet the individual grains over their whole surfaces, the whole mass being shoveled constantly during the spraying.

He also recommends highly Formalin (HCOH), a liquid with marked antiseptic properties, and used in the same way as Corrosive Sublimate, but the proportions 1 to 1,000.

LOOSE SMUT OF WHEAT.

(Ustilago tritici (Pers) Jensen.)

This smut is a very different one from the last in many respects.

Fig. 5. Fig 6.

In the first place it does not conceal itself within the bran of the wheat, as does the bunt, but attacks chaff as well as kernel, devouring both, and leaving behind it, when its work is completed, only the blackened rachis or stalk of the wheat-head. In the second place it has no foetid smell. In the third place it ripens at about the time the good ears of wheat are coming into flower, and not at harvest-time, as does the bunt.

It is not nearly so destructive as the bunt, attacking fewer individual stalks in a field, but it is none the less to be dreaded by the careful husbandman, because it yields much less readily to treatment. And yet it is occasionally not far behind the bunt in the injury inflicted. While the bunt will take as high as 75 to 80 per cent of the crop at times, the loose smut has been reported in a few instances to have destroyed as high as 50 per cent of an entire crop. As the spores ripen and

Fig. 5. Head of wheat affected with loose smut in the lower half.

Fig. 6. Head of wheat affected with loose smut-harvest time. —Swingle, Year Book for 1894, Dept. of Agr.

are mainly carried away by the wind before the grain is ripe, this form of smut is often entirely everlooked by the farmer. But this same wind has given them a hiding-place amongst the good ears as well as on the ground, and they are consequently in great numbers threshed with the good grain and stored away for reappearance the next year.

LIFE HISTORY.

The life history of this fungus is very similar to that of the bunt or stinking smut. It is planted with the seed, germinates about the time the wheat germinates, and attacks the young plants in much the same way as does the bunt. It forms the same thread-like filaments that permeate the entire stalk of wheat, growing up to and into the head, and living off of the elaborated sap of the host It attacks the head, as said before, when this is in the flower, and feeding upon the young ovary stamens, and even chaff of the flower, produces its spores in great abundance. These spores can be told from those of the bunt with great ease, if you are provided with a moderately good microscope. While the spores of the bunt are perfectly smooth, or in one species covered over with a net-work of delicate ridges, those of the loose smut are covered over with little prickles, or rather small, sharp elevations. Before the blackened remains of the head appears, the affected plants can often be told by the following means: They rarely grow as high as good stalks, though they are generally thicker, greener, and bear the heads, especially in affected oats, a little more erect. The curling of the awns of the awned wheat and oats is often another indication of its presence. Stools like these it is always well to pull up before the ripening of the smut-spores can occur.

REMEDIES.

None have been tried at our station, to my knowledge, with this form of smut. Swingle* recommends the following, "The grain must be soaked four hours in cold water, then set away about four hours more in wet sacks, and finally treated as directed above, (See Hot Water Treatment) but only for five

*The Grain Smuts: Their Causes and Preventions. U. S. Year Book for 1894.

minutes, at 132 F. In planting, use one-half more seed per acre to compensate for the seed killed by the treatment."

From numerous experiments it has been shown by Kellerman and Swingle* that the ordinary treatments for stinking smut will have no effect in preventing the recurrence of loose smut.

The surest cures for this disease, as known at present, are mainly preventive ones such as rotation of crops, or, where wheat is the main staple, care exercised in the purchase of clean seed, and summer-fallowing a part of ones farm each year.

LOOSE SMUT OF OATS.

(Ustilago Avenae (Pers) Jensen.)

This widespread pest in oat-fields was for many years judged to be the same fungus as the loose smut in wheat. The life history, general aspect, and effect upon the oat-flower are essentially like those of the wheat-smut, but the fact that it has some little botanical difference from the last-named, and the important fact that it is much more amenable to treatment, have led to its being placed in another species. Its black, unsightly appearance amongst the oats is too well known to need comment, for it is as common an enemy to the oat-grower in Idaho as are the two last mentioned fungi to the producer of wheat. It is generally much more easily seen amongst the growing crops than is the loose smut of wheat, for from every spray and flower of the diseased panicle it hangs out its black piratical flag, (see cuts on page 21) which is only hauled down when flower and chaff are completely destroyed and gone. The loss incurred from this fungus throughout the United States, as has been before shown, mounts into the tens of millions annually. And yet it is almost as readily prevented as is the stinking smut of wheat.

REMEDIES.

No special experiments have been made at our station to test the value of fungicides, but the fact that the different rows of oats planted in '96 for variety tests, and with no treatment for smut, sometimes gave averages of smutted heads as high as 18 to 20 per cent, would prove conclusively that tests upon the value

*Bulletin No. 22, Kansas Experiment Station.

of different fungicides, especially of those known to be effective in prevention, would be very pertinent.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 7. Head of oats affected with smut, but having the chaff only partially destroyed.

Fig. 8. Head of oats affected with smut, having the chaff only partially destroyed; decidedly smutty.

Fig. 9. Final stage of smut, showing condition of head at harvest time—Swingle, Year Book for 1894, Dept. of Agr.

These experiments will probably be undertaken with the next sowing of oats.

The hot water treatment has been tried by the U. S. Department of Agriculture as well as by numerous stations and has been found to be highly effective and remunerative. This latter fact is the more obvious when it is remembered, as has been conclusively shown by many experiments, that the yield of oats under the hot water treatment is far in excess of what we would be led to expect,—or in other words, *the per cent gain in treated grain is much greater than the per cent gain from grain which is unsmutted but untreated.* Many reasons have been adduced to account for this gain, but it is probably due to its increased germinative power and its consequently increased vitality. Bolley has noted the same thing with wheat treated by the corrosive sublimate treatment, due, as he says, in great measure to its lessened liability to decay.

Another very effective method of treating oats for oat-smut is what is known as the Potassium Sulphide (or "Liver of Sulphur") Treatment. This substance can be obtained from most druggists at about 50 cents a pound In many of the large centers in the West it can be obtained for about 30 cents a pound. Swingle* recommends the following: Keep the potassium sulphide in a tight glass vessel, protected from the air, until ready for use. Dissolve 1½ pounds in 25 gallons of water in a wooden vessel; a a tight barrel is very good for the purpose. The lumps of potassium sulphide dissolve in a few minutes, making the liquid a clear yellowish-brown color. After thoroughly stirring, put in about 3 bushels of oats and agitate well to insure wetting every grain. The solution must completely cover the grain and be several inches above it, as the grain soaks up some of the liquid. Leave the oats in this solution twenty-four hours, stirring several times during the day to be sure that every kernel is wetted. Then spread out to dry. In treating large quanties of seed, a hogshead or wooden tank might be used. The solution should not be used more than three times. In no case should any metal be allowed to come in contact with the liquid. This treat-

*Year Book of U. S. Dept. of Agr. 1894.

ment is thoroughly effective for oat smut, and is worthy of trial for stinking smut of wheat."

On the other hand, Bolley* says of the Potassium Sulphide Treatment: "I cannot recommend this treatmeut for farmers who wish to rapidly handle large quantities of seed. It is disagreeable in its nature. It prevents the grain from drying, and results in irregular sprouting if the wheat is kept any length of time. As far as tested it does not sufficiently prevent the smut without long periods of soaking.

This alone makes it undesirable upon large farms. A special form of this substance has lately been placed upon the market under the name of 'Ceres Pulver.' This is said to be more efficient and may yet prove to be of economic value for wheat treatment."

SMUTS OF BARLEY.

(Ustilago hordei (Pers) Kell. & Swing. Ustilago nuda (Jens) Kell. & Swing.)

The first of these is known as the Covered Smut, because the spores are covered by a thin membrane up to the time of harvest. The other is known as the Loose Smut of Barley, and in form closely resembles the Loose Smut of wheat, completely disappearing soon after the time of flowering. The first of these has not been thus far seen in Idaho, the last in but limited quantities. Both can however be effectually surpressed, according to Swingle, by the hot water method, preceded by the cold soaking. This method was described under remedies for Loose Smut of Wheat, which see.

SMUT OF CORN.

Ustilago Maydis (DC) Cda.)

As corn is but scantily produced in Idaho, and as the smut peculiar to this host has been seen in but few fields, it needs very little said about it. As none of the ordinary fungicides affect this smut, all the more care should be taken to extirpate this disease wherever found. This can be done by simply walking along the rows, inspecting the plants for this very conspicuous fungus

*Bulletin No. 27 North Dakota Ex. Station 1897.

and when found destroying it. It is generally seen disfiguring the ear, or occasionally the place where the ear ought to be, with a mass of bluish-black boils. It sometimes attacks the tassel, leaves and stalk. If it be found infecting the ear, pull off the ear and burn it, or bury it deeply in the earth. If it affect any other part of the plant, is is better to destroy the whole stalk. This destruction should always take place while the black mass is full of juice. If you wait till it is dry, it will most likely disgorge a quantity of its black spores before it can be carried out and destroyed. Never, if it can be avoided, gather smutted stalks or ears for cattle to destroy. Though these are not injurious to stock, at least in limited quantities, the spores will last over winter in the manure pile, to be hauled out over the farm and taint the seed when planted, or the corn when growing.

THE RUSTS OF GRAIN.

While the smuts of grains inflict great losses upon the farmers of the country, they can be controlled by careful methods, and the losses, in most cases, reduced to a minimum. With the rusts, however, it is a very different matter, for they have so far defied all fungicides, whether applied directly to the seed or in the character of sprays. Another point about the rusts is that they work much more insidiously. They manifest themselves in more limited fruiting-areas on their hosts, do not directly attack the kernels of grain, or even the heads, and are consequently neglected by the most of our farmers or entirely misunderstood. Any farmer sees that the smuts destroy his grain while on the stalk, and just so far detract from his yield. Few of them on the other hand realize that the rusts, which manifest themselves in little yellow, red, or black spots on the culms and leaves of the grains, are just as surely sapping the vigor and detracting from the yield of his crop as if they took the grain itself for their places of reproduction instead of the stems and leaves. And it is remarkable how little attention is paid in many places to those little plunderers. I have asked farmers in the Palouse country, whose farms I had inspected and whose stubble I had seen in places almost black with the winter-spores of rust, wheth-

er they had seen any rust on their grain or on that of their neighbors, and have received the answer: "None to speak of." Suffice it to say that the rusts are very common in Idaho, and I doubt whether a section of wheat can be found that is not more or less affected. If they are so common, how can they best be combatted? Before I answer this question we must glance shortly at their life history.

LIFE HISTORY OF THE GRAIN RUSTS.

The Rusts belong to that class of fungi that take two or more generations to reproduce the original kind. These different generations were at one time, and that not very long ago, thought to be different plants or fungous diseases, and were so named. But now, through the admirable researches of De Bary and others, we know that these diseases, that formerly went by the names Uredo, Puccinia and Aecidium, are all forms of one genus of fungi, and we call that genus Puccinia. There are three species af this genus that do the most damage to cultivated grains and other grasses as well as to many wild ones. Two of these, Puccinia graminis and Puccinia rubigo-vera, devote their main attentions to wheat, barley and many grasses, while the third, Puccinia corronata, attacks the oat. The life history of all of these is so similar that an explanation of one, with slight modifications, will do for all.

If a person go out into almost any wheat-field in the Palouse country in the late spring or in early summer, he will find the lower parts of the stalks and the leaves of the wheat or barley dotted with small yellow or orange dots, somewhat longer than wide, and apparently covered with powder. (See cut page 26.) If he should examine one of these dots with a good magnifier or an ordinary compound microscope, he could make out that this yellow or orange dust is really made up of a quantity of little spores, raised upon stalks, and in some cases bursting through and turning aside the epidermis of the grass, in others not yet burst through but visible through and just under the epidermis. This is the first stage in the growth of the rust, and is known as the Uredo-spore stage. If part of this orange "dust" be now placed on a slide, and more highly magnified, it will be

Fig. 10.

plainly seen to be made up of quantities of bright, spiny spores, round to oval, and separated from or still adhering to the little stalks that support them. (See Fig. 11.) If some of these spores be placed in a drop of water, and this prevented from drying up for a few hours, those little spores will be found to have sprouted, and to have sent out a little tube. (See Fig. 12.) If these spores, which are easily blown from their place of growth, lodge upon the leaves of grasses or grains, and the weather be warm, and moisture due to mist, dew, or rain abundant, those spores germinate just as they did in our drop of water and send out their germ-tubes, which eventually find an entrance into the leaf through the innumerable breathing-pores that dot the surface. Once inside, this tube ramifies through the soft tissues of the leaf or stem, and soon loses all connection with the spores, to find its sustenance in the tissues of the host. Soon this ramifying tube, or mycelium as it is now called, produces sori or fruiting dots like its parent, and thus the pest is continued through the spring and early summer. About this latter time, and continuing late into the fall, a second generation or kind of spores is formed proceeding from the same sori from which came the early spores, or similar ones. (See Fig. 13.) These are two-celled, oblong or elliptic, dark-brown spores, which when massed together look black, and hence

Fig. 10. Wheat leaf, showing the spotting done by "red-rust" (Uredo rubigo-vera DC.) Natural size.—Bolley.

have been called from time immemorial

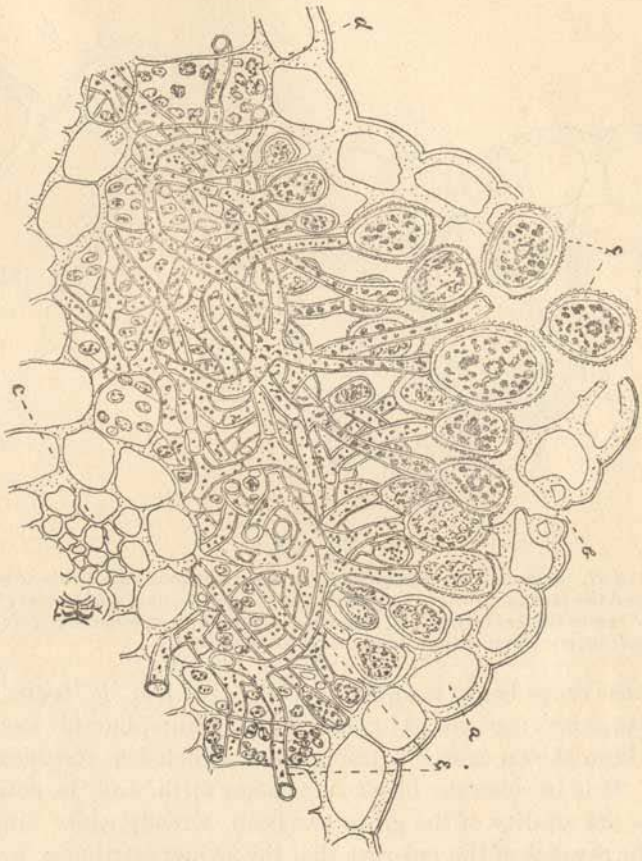

Fig. 11.

Fig. 11. Cross section of a pustule of rust in the "red" or summer stage of P. rubigo-vera, showing the relation of the spore to the host tissues and the fungal hyphae from which they arise; (a) epidermal layer of cells ruptured and thrown back by the developing spores; (b) stomatal opening or breathing pore; (c) a portion of the leaf vein (fibro-vascular bundle) seen in the cross section; (d) a cell of the mesophyll area containing chlorophyll bodies not disorganized by the action of the fungus; (e) fungal hyphae which absorb nourishment from the cells of the wheat plant; (f) mature spores which have been pushed off from their pedicels by the spores which arise from below. X 400.—Bolley.

"black-rust," to distinguish it from the earlier form, the "red-rust." It is too often the vulgar opinion that "the red-rust does not do much harm, but when the black rust strikes the grain,

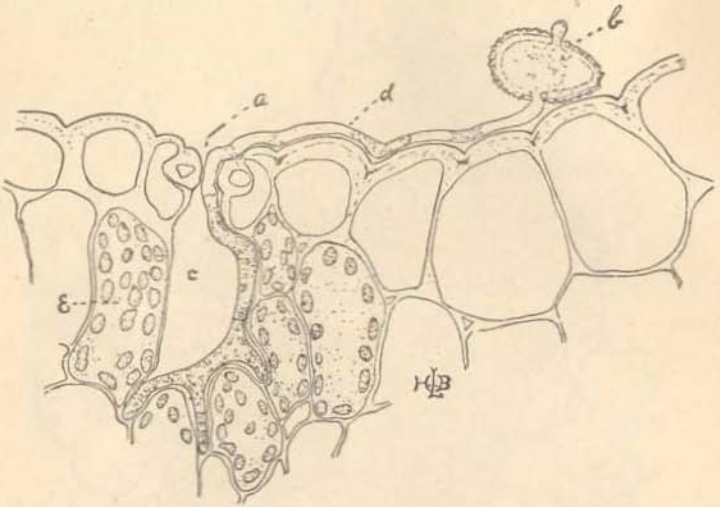

Fig. 12.

Fig. 12. A portion of a cross section of a wheat leaf showing a stoma or breathing spore and the manner in which the germ tubes of germinating uredospores ("summer spores") enter the leaf tissues; [a] stomatal opening; [b] a germinating spore; [c] air chamber; [d] mycelium or germ tube. X about 350.—Bolley.

then the crops begin to suffer." Not only has it been shown that the two rusts are not two different plants, but it has likewise been shown that it is the red-rust which does the most damage. It is because the black-rust comes forth and is noticeable when the vitality of the grain has been already sadly impaired by the ravages of the red-rust that the farmer attributes the greater effect to the former. He forgets or does not know that while the grain has been growing the fungus has likewise been thriving, and that sapping process has been going on all spring and summer; that the black-rust is only a form the plant takes when it wishes to rest throughout the winter. However it is perfectly immaterial, at least to the raiser of grain, which form of rust does the most damage, for neither can exist for any length of time without the other, or at least without producing the other. But the end is not yet. The spores of the black-rust, known as teleutospores, are capable of enduring the cold of winter, and they germinate when the weather will permit of it in the early spring.

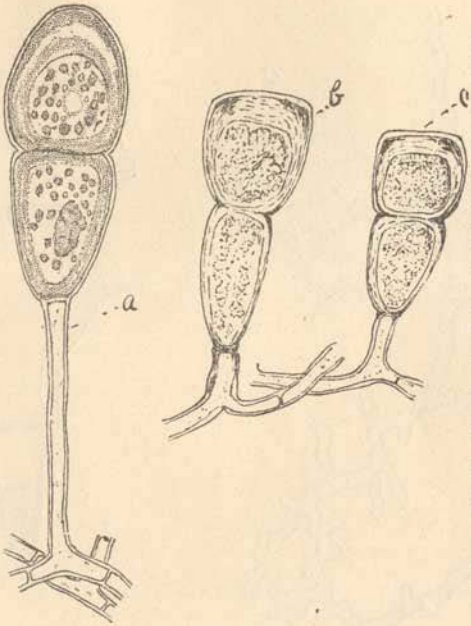

Fig. 13.

Fig. 13. [a] Mature teleutospore ("resting spore") of P. graminis; [b] and [c] Mature teleutospore of P. rubigo-vera. All highly magnified.—Bolley.

The teleutospore sends out a branched tube, the branches ending here and there in minute spore-like bodies, called sporidia. (See Fig. 14.) Now it would be thought that these sporidia, alighting on a leaf of wheat or other grass, would germinate, enter the breathing-pores of the leaf with its germ-tube, produce the uredospores and our cycle of existence would be complete. Nothing of the kind, and here comes in the marvel of the thing,—a marvel which is due to the researches of the renowned German scholar De Bary. For years before his time farmers and scientists had noticed that the proximity of the common barberry, Berberis vulgaris, to a field of wheat was often accompanied by a severe attack of rust, and it was suspected that the barberry was in some unknown way accountable for the unusual amount of diseased grain. It was reserved for De Bary to prove beyond a doubt that the sporidia of the rust would not germinate upon or in the leaves of grain and grasses, but would and do germinate upon the barberry leaf, and here produce the third stage in the growth of this curious fungus, known as the cluster cup, or Aecidiospore stage. (See Fig. 15.) It is not my purpose here to enter into a long scientific description of these three stages of the disease. If knowledge on these points is desired anyone can find the matter detailed in a much more scientific

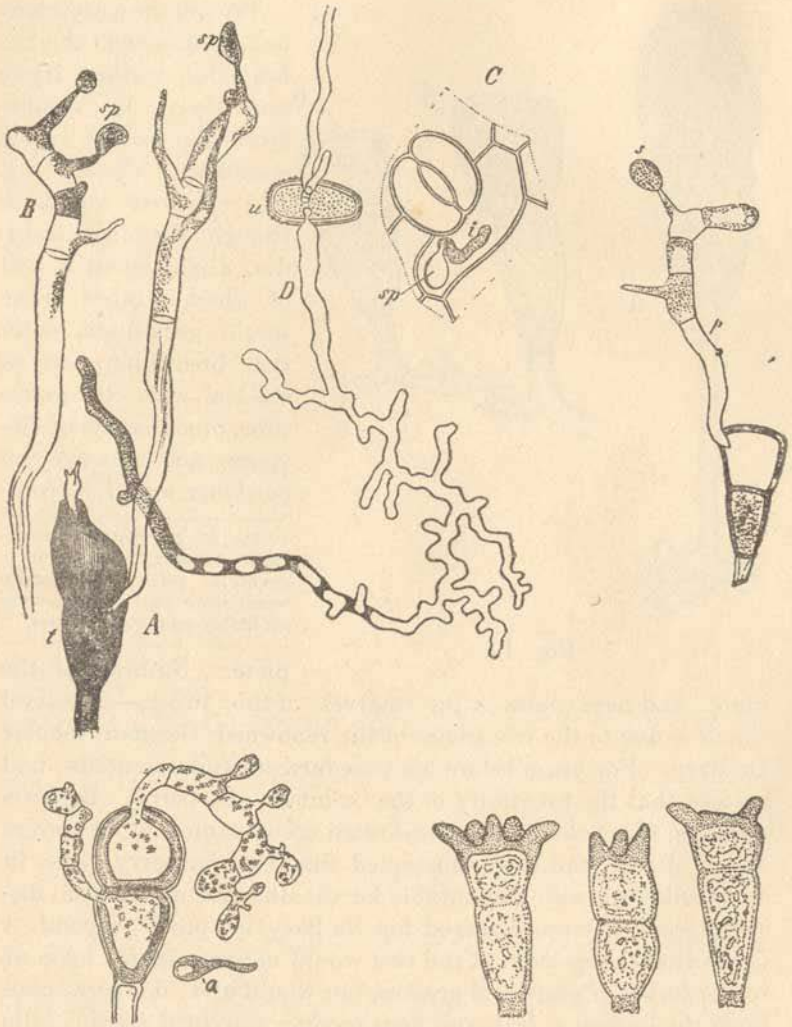

Fig. 14.

Fig, 14. Puccinia graminis; [A] "winter" or teleutospore: [t] germinating. [B] germ-tube [promycelium] with lateral sporidia sp. [C] epidermis of under surface of leaf of barberry showing crescent shaped cells of the stoma and the germinating sporidium sp. at i penetrating the epidermis. [D] uredo spore germinating after being in water fourteen hours. [E] Puccinia rubigo-vera, the upper cell has germinated. [C, D, E] magnified 390 times, the others somewhat more. [After De Bary.] [F] Puccinia gram-

inis, Pers.; both cells have germinated; a, a sporidium germinating, magnified 600 times. [After Bolley.] [G] Puccinia coronata, Cda.; telutospores of rust on leaves of oats, magnified about 600 times. [After Bolley.]

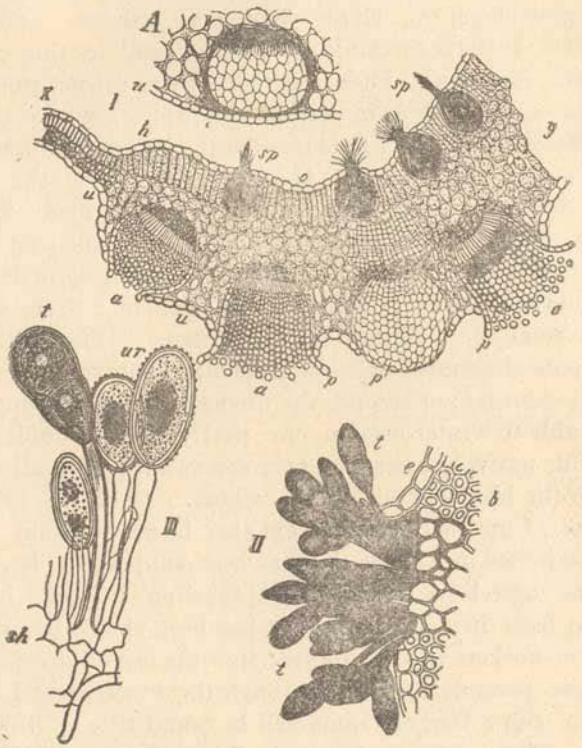

Fig. 15.

Fig. 15. Puccinia graminis, Pers. A. young cluster cup fungus [Aecidium,] underneath the epidermis, u, of barberry leaf. l, section through an older lefa, flask-shaped bodies [spermogonia] shown at sp; the aecidia and spores in chains at a; p, cells lining aecidia [peridial cells, these do not germinate.] Æcidia occur on lower surface of leaf. II, t, ripe "winter," "resting" or telutospores at e, epidermis. III, t, telutospore and uredospores ur. [After De Bary.]

manner than I choose to give, in many of the very exact descriptions to be found in the bulletins and scientific works of this and foreign countries. It is my purpose to give our agriculturists an adequate idea of the life of these fungi simply to show how they can be combatted, if at all. There is another matter that is equally interesting to the scientific man and to the enlightened farmer in

this country and that I shall be excused for giving in full. While no one now questions the truth of De Bary's great discovery of the growth of the sporidia upon the barberry, producing the Aecidiospore-stage, by whose spores the grasses and grains are infected, there is certainly a "missing link" in this chain on this coast. It is a well known fact that there are not probably a dozen places, to speak from personal knowlelge, where the barberry is cultivated in the Palouse country, and in none with which I am acquainted is the Aecidiospore-stage of the fungus found. Neither to my knowledge is it produced upon the wild barberry, or Oregon Grape, Berberis repens. And yet in the early spring some of the sori or dots of the Uredo-form are found, to be followed later by great quantities of them. From this, it seems that one of two things must be true. First, either the Aecidiospore-stage must exist on some other host than the barberry, in this country; or second, the uredospore and its mycelium must be able to winter-over in our partly-alive stubble or on some of our native grasses that keep somewhat green all winter, or within the blades of our winter wheat. Of these two mere hypotheses, I am inclined to accept the latter. From experiments conducted in Europe this has been supposed to be impossible, the mycelium in the stubble showing no life in midwinter, at least in P. graminis. It has been shown by some of our station-workers in this country that the mycelium of P. rubigo-vera *does* perennate, or live through the winter, and I am inclined to think that the same will be found true of that of P. graminis. The aecidiospore stage in this latter does not occur on the barberry, but on some of the Borrage family. As we have a great number of genera and species of this order on our coast, it may be found that this Aecidiospore finds as comfortable quarters with some of them as upon the eastern species.

The cycle of the oat-rust, Puccinia coronata, is much the same as that of the last two, so no special attention will be devoted to this species, especially as it very rare so far in Idaho.

REMEDIES.

I have shown under the last heading that these diseases, unlike the smut, do not attack the seed or the growing plantlet

when under ground, but develop on the green tissues, or the above-ground portions; that while the smuts are not at all contagious, the rusts are altogether so. It is therefore of no use to treat the seed. A few experiments have been tried of this nature, but they have all availed nothing. The next question would naturally arise, will spraying do any good? From the experiments of Kellerman and Swingle conducted upon the Kansas Station in 1891, and from the more recent experiments of Hitchcock and Carleton at the same station, as well as from those of Pammel in Iowa, it has been demonstrated that our present fungicides have no marked effect if any in lessening rust. What then is to be done? Are we to allow this pest to run, as it were, red-handed through the grain fields? Unless most careful means are used in other directions than those mentioned, this state of affairs must continue to be the case.

What are the losses, and how long have they been known? Bolley thinks that the 7 years' scarcity on the Nile in Old Testament times was probably due to this disease. As mentioned in the beginning of this paper, it was well known to the Greeks and Romans. As to the matter of loss by this cause, there are some parts of the United States where they have ceased raising wheat, so great is the destruction of standing grain through rust. In other states the loss is variously estimated at from 10 to 15 per cent of the whole crop. Bolley shows us that were the loss from this cause alone put as low as 1 per cent of the crop raised in the United states, and it is conceded that this is ridiculously low, it would exceed $4,000,000. It is probably nearer $10.000,000. It certainly then behooves us to find every means to lessen this loss, if we can not eliminate it. Some of the methods used to this end are the following, when a field has shown abundant rust.

1. Let it lie fallow for a year, or, where such is possible, put it into some other crop than a cereal. One year's cultivation will kill out all the spores remaining on the ground, as will a year's summer fallow if all volunteer wheat is plowed under.

2. If such fallow land is not to be plowed, then pasture closely to keep down any vegetation upon which the rusts can get a hold. They flourish nearly equally well on grasses.

3. Where the person cannot afford to summer-fallow land,

if such a state of affairs be admitted, and a cereal must be followed next year by a cereal, burn over the stubble, burn all piles of infected straw (as they will infect the field, and are unfit for food for stock), and haul out upon the farm no poorly-rotted and therefore possibly smutted or rusted straw.

4. All wheats suffer from rust, but the early ripening ones suffer least; therefore where rust is abundant plant early varieties.

5 The varieties with straight, stiff leaves are affected less than those which have weak foliage: and the varieties which have thick-skinned leaves, or whose leaves are either smooth, allowing no holding-place for the spores, or very hairy, holding the spores but at such a distance from the leaves that they fail to germinate, or germinating fail to infect the leaves, are the best to plant.

6. Don't sow wheat on stubble-land, where rust has been abundant, for the stubble is often black with winter spores, or is capable under certain conditions of lasting green and thus alowing a place of development to the Uredospores.

7. It seems that the red wheats are least affected, while the white varieties, notably Velvet Chaff, are most subject to rust.

8. Poor drainage and an excess of nitrogen in the soil seem also to aggravate the evil.