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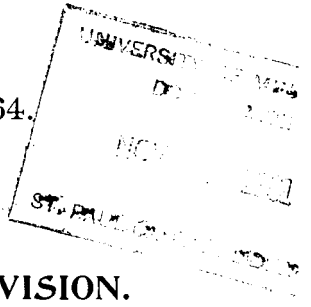

BULLETIN NO. 64.

ENTOMOLOGICAL DIVISION.

OCTOBER, 1899.

THE BLACK RUST OR SUMMER RUST.
THE HESSIAN FLY.
MIGRATORY LOCUSTS OR GRASSHOPPERS.

ST. ANTHONY PARK, RAMSEY CO., MINNESOTA.

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INTRODUCTION.

Owing to the heavy losses to the grain in many sections of the state, caused by certain insects and vegetable diseases, and the fact that more and still heavier losses may be caused in the near future, unless farmers take time by the forelock and immediately go to work to at least partially prevent a repetition of them, the following bulletin has been prepared at the request of His Excellency, Governor John Lind, who has always taken deep interest in the welfare of the farmers of Minnesota, our true wealth producers. If the advice given in this bulletin is followed, and followed in time, much injury to our cereals may be avoided.

OTTO LUGGER,
Entomologist.

THE BLACK RUST OR SUMMER RUST.

OTTO LUGGER.

Our cultivated plants are frequently more or less injured by many different kinds of animals, insects, and parasitic plants or diseases. From time to time all these cause immense losses to the tillers of the soil, since they appropriate for their own use that which the farmer and gardener intended to use for himself, for his family, or for his stock. The farmer can see the larger of such intruders, and can fight them, frequently with good results. But such minute enemies as rusts, almost invisible as individual plants, but very prominent in the effect of their united work upon our small grains and grasses, he can not fight as well, nor can he greatly lessen the injury caused by their presence. In fact the great majority of our farmers do not even know or suspect that they have to fight against living organisms, against active, growing, and rapidly multiplying parasites; but they believe the rust to be simply caused by climatic conditions, by something indefinable in the air, or by some evil influence in the soil or water. They simply express their opinion by saying that the plants are sick; which is only too true, and sad experience tells them that such sickness will ruin their bright prospects for a rich return of their labors in the grain fields. *Rusts,* like the closely related *blights* and *smuts,* which are also caused by lowly organized vegetable organisms, truly blight the hopes of all farmers whose fields are invaded by them.

All those persons who had observed the promise of a big

yield of wheat on our fertile fields, so densely covered with the tall, golden-colored plants, waving in the bright July sunshine, did not suspect that in this case appearances could be so deceptive, but felt certain that a bountiful crop would be harvested. Yet many farmers have been sadly disappointed, for many heads of wheat are but poorly filled, or the kernels are not as perfect or plump as they should be to bring a good price. Whoever has experienced this unpleasant surprise, should know that these shrunken and shrivelled kernels are caused by the presence of rust, and especially by that of the *Black* or *Summer Rust.*

It is not necessary to enter into a detailed account of the three kinds of rusts that can become so injurious to our small grains, as all are very similar in their general appearance and their effects on the plants. All are parasites of the worst kind, and all abstract from the infested plants those substances that were taken from the soil by the latter to produce seeds.

The general belief that rust comes with rain after a very hot day is not wrong, only rain and hot air are not directly the cause of the trouble, but act simply as the carriers of it. Many experiments have shown that the minute bodies, or spores, causing the rust, are carried into the atmosphere from the infested plants by a current of air produced by the unequal expansion of the air by the sun. It will be seen that the air near the dark ground heats up quickly, and becoming lighter in consequence, rises, and in so doing carries with it the loosely attached spores of the parasitic rust. Such spores are really the seeds of the rust, called by another botanical term simply because they are produced in a different way than common seeds; yet they possess the same functions: they produce new plants. These spores are carried in the air by the upward current, and if they reach a certain altitude they may float during the day for hundreds of miles. Like balloons, they are so light that they are at the mercy of every current, nor do they descend so long as there is still a current of air rising from the ground. They can not return to mother Earth until evening, when they descend with the heavier humid air, and with the dew. Of course if it should rain during the day they

are brought down again with most of the other floating impurities in the air. If it should rain hard they are brought down to the very ground, and leaves of grain coated with them are washed clean. This is a bad thing for the spores, but a very fortunate occurrence for the owner of the plants, as such spores are lost forever, or, what is as good, are unable to cause further trouble. As they come in contact with the moist soil they soon germinate, and not having a chance to reach the green leaves or stems of wheat, etc., they perish in a very few hours.

A heavy rain following a hot day is therefore of benefit to the farmer and injurious to the parasite. But if moisture comes down as a fine mist, or during the night as a heavy dew, then the spores reach the leaves and stem of the host, i. e., the invaded plant, and, being surrounded by moisture and warmth, they soon sprout and enter the plant.

It is frequently said that certain fields are worse infested than others, and sometimes an explanation is difficult to find. But when we recollect that on a very warm day, without any wind, the spores are simply carried upwards, and during the night downwards, we may find an explanation for the fact that rust is always worse behind wind-breaks and other shelters than anywhere else, simply because in such places the air is stagnant, and all the spores produced there are only too apt to lodge again upon grain planted in such sheltered places. Rank plants, caused by manure or by any other means, are also quite frequently injured more than the drier plants growing elsewhere, for very self-evident reasons. Grain planted early, with a moderate amount of foliage, usually escapes to a large extent the rust, while neighboring fields with a more rank growth will suffer.

As this bulletin is intended for general distribution among farmers and others interested in agriculture, or to people possessing all degrees of botanical knowledge, it is rather difficult to treat this subject in a popular way. In describing *fungi*, a family of plants to which rusts, smuts, blights, etc., belong, we must necessarily use some botanical terms, because the English language, though so rich in words, does not possess any to denom-

inate the parts and organs of such lowly organized and microscopic plants, for the simple reason that it was formed long before the existence of any extensive botanical science. But the writer will endeavor to make the description as plain as possible, and the illustrations will go far to assist the reader in understanding them. The illustrations are, in part, taken from a book by W. G. Smith, entitled "Diseases of Field and Garden Crops."

Rust is a parasitic plant which enters the *host,* or infested plant, and there causes disease. It is carried by wind and rain, but not caused by either. To show how the spores of rust look, or how they enter the hosts, figures 1 and 2 are given. Fig. 1, enlarged 1,000 times, shows two summer spores (uredospores), one in the act of sprouting.

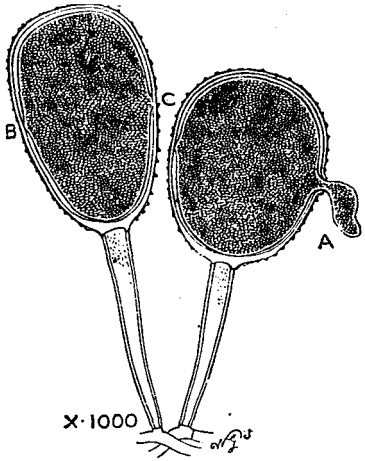


FIG. 1. Uredospores in the act of sprouting. Enlarged 1000 diameters.

This operation can be studied by keeping such spores in moist air for a few hours. Germination takes place by the protrusion of two germ tubes or threads of mycelium, one from each side, and usually near the middle, though sometimes from or near the top of the spore. The spots whence the tubes emerge from the

spores can often be detected even before germination, as here the walls are weak, as can be seen at B and C. At A one of the tubes has broken through the walls.

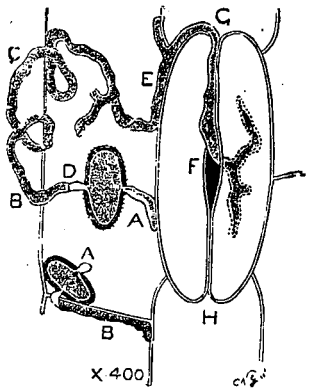


FIG. 2. Two summer spores (*uredospores*) growing upon a bit of leaf. Enlarged 400 diameters.

In Fig. 2 we see two summer spores (uredospores), enlarged 400 times, growing upon a bit of leaf of wheat. As a very general rule only one of the germ tubes grows, while the second one, as seen at AA, remains short or inactive. The larger and stronger tube keeps on growing in a convoluted fashion, as at C, and in a day, or a day and a night, it has attained many times the length of the spore from which it grew, and which is now entirely empty and falls to the ground. But before this happens a partition, or *septum,* has formed, as at D, which separates the living from the dead tissue. When we carefully watch one of these slender germ tubes under a microscope, we shall be greatly surprised, as it now looks like a living worm, and it moves or flows into any little scratch or depression on the glass. Now, why should it do so? When we study the structure of a wheat leaf we will at once find an explanation. We find that it is the aim of this tube to enter into the tissue of the leaf, and this it can not do unless there is an opening provided for this purpose. And there are many such openings, namely the minute mouths of a leaf, organs

of transpiration, called *"stomata."* One of them is shown at F, and it will be seen that the tube follows the depression E until this opening is reached. Such stomata are the lowest points on a leaf surface; hence the germ tube can not fail to reach them. One of these worm-like tube enters, and soon disappears from sight (see dotted outline). Once inside, it branches out right and left, and soon ramifies amongst the green cells. Here it produces a plant called a *"mycelium,"* composed simply of fine and delicate threads. In a short time it produces large numbers of new summer spores (uredospores), which break through the wheat cuticle a short time afterwards, and on reaching the surface form the well known rusty-brown pustules. The mycelium is of a brownish color, and is shown in Fig. 3, between the cells of the wheat leaf at C, and the spores. The latter try to force their way through the three mouths or organs of transpiration at B and at D, D. This illustration, which is a transverse section through the rusty-brown pustule (or *sorus*), also shows the closely packed summer spores (uredospores). These are supported upon transparent pedicles or stems, as can be seen in Figs.

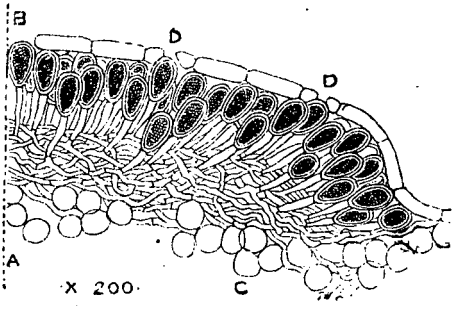


FIG. 3. Transverse section through half a pustule or sorus. Enlarged 200 diameters.

1 and 3. The spores in a sorus vary to some extent in shape and size, no two are exactly alike; still they vary only within well-defined limits.

Early in summer leaves of the wheat plant infested with these parasites show rusty-brown spots: the pustules or sori. Fig. 4

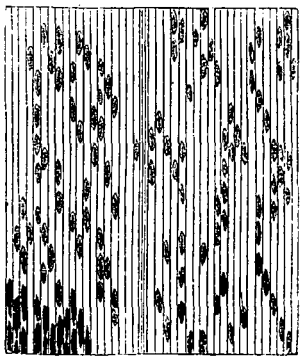


FIG. 4. Fragment of wheat leaf invaded by rust. Enlarged 3 diameters.

shows a small piece of such a leaf enlarged three diameters, and in Fig. 5 we see one of the pustules still more enlarged. Here we find that the skin is ruptured, and that immense numbers of sum-

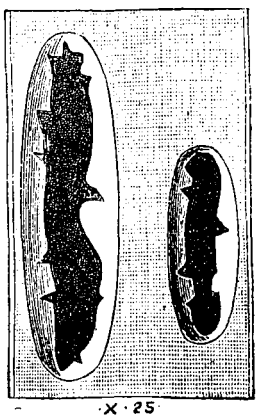


FIG. 5. Pustules or sori. Enlarged 25 diameters.

mer spores are crowded together, waiting to be torn off by the wind and to be carried to other and still uninfested parts of the same or other wheat plants.

One generation of summer spores (uredospores) follows the other, and as long as the infested wheat plant can still furnish

liquid food there is no cessation. Sometimes very heavy and repeated rains will improve conditions very materially, as they are apt to wash off all the exposed spores, and thus make them harmless. Of course more moisture will also produce fresh and uninfested new foliage on the top of the plants. The writer has even seen that the army-worms, by no means desirable visitors to our grain fields, were actually of benefit, as they devoured the leaves, rust and all, and thus materially assisted the plants to get rid of these parasitic vegetable intruders.

As the wheat plants ripen and become dry, no longer furnishing liquid food, the parasitic rust-plant is also forced to stop

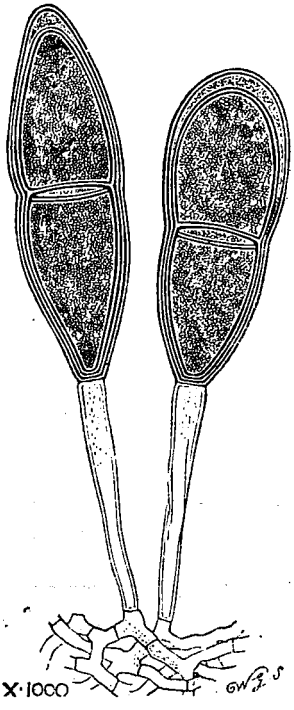


FIG. 6. Winter spores or Teleutospores. Enlarged 1000 diameters.

operations for the summer. This it does by producing different kinds of spores, the winter spores or teleutospores, two of which

are shown in Fig. 6. By comparing Fig. 1 and Fig. 6 we can at once see a great difference between these two kinds of spores, and it is hardly necessary to draw the attention of the reader to them. Not alone do they differ in size, but it will be seen that the winter spores are always united in twos. Besides, they are very much darker, possessing heavier coats than the summer spores, and for good reasons, as the parasites have to hibernate in this shape.

A transverse section through half a pustule or sorus, as found late in the season, shows the winter spores also crowded together, ready to force their way through the ruptured skin. These spores possess larger stems. Such a section is shown in Fig. 7.

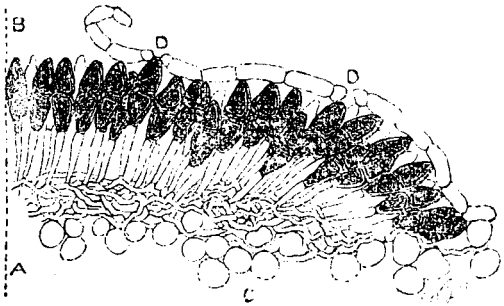


FIG. 7. Transverse section through half a pustule or sorus, showing the winter spores. Enlarged 200 diameters.

Now what becomes of these winter spores or teleutospores? We know that they are well protected against the cold by double coats of thick skins, that they are not killed by frost, and that they will readily germinate the next spring. We also know that there are now untold millions of winter spores upon the dead leaves and stems of all kinds of small grains and grasses in the infested regions, and if these spores could again invade the healthy young plants the next spring, it would be folly to expect any of the latter to thrive, since they would soon be invaded by the parasites and be destroyed. This would be a sad state of affairs, and farming would soon have to cease. For these reasons it is important for our farmers to know exactly what they have to expect, and so let

us follow the life-history of these destructive plants still further. We shall see that the parasites have an immense power of destructiveness, but that there is also a limit to their continuous increase. Their life-history is very similar to that of many lowly organized animal parasites, for instance to that of the nasty tapeworms, which have to pass through other animals, and through an entirely different form, before they can again appear as tapeworms in the human being. We know that the winter spores are not killed by frost, but we also know that they can not again enter the tissues of grains and grasses, but that they have to pass

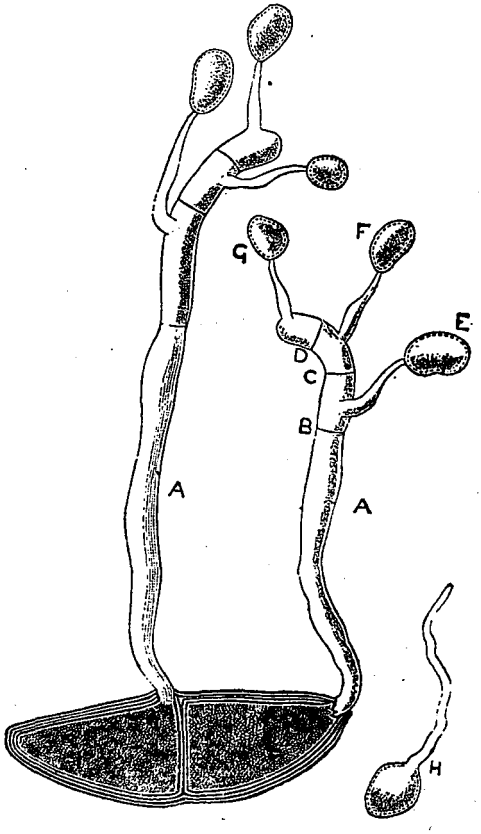


FIG. 8. Winter spores (Teleutospores) germinating in spring. Enlarged 1000 diameters.

through another plant, in which they produce an entirely different disease, before they can again become destructive to our main staples, the cereals and grasses.

If during the spring we take a small knife or a needle and remove some of the black spores found in the pustules of the invaded straw, and place them in a film of water on a slide under a thin cover-glass, and keep this in moist air under a bell-jar, to prevent evaporation, we can observe that germination usually takes place by the protrusion of a thread from each of the two cells of the winter spore. In Fig. 8 we can see the whole operation. These two threads, the first produced in spring, are called the *pro-mycelium,* or the first mycelium. They are the beginning of the cycle which has for its last form the winter spores or teleutospores. The pro-mycelium is seen at AA. It does not grow to any great length, but after attaining three to four times the length of the black winter spore, it usually coils round somewhat like a shepherd's crook. It produces about three stops, joints, or *septa*, as at B, C, D, and from each of these three separate pieces a fine branch is produced; each bears an irregular, oval, transparent and very pale amber-colored spore at its end, as shown in E, F, G. These are the third kind of spores we have found, as we have already had the rusty-brown summer spores (uredospores), the blackish winter spores (teleutospores), and lastly, the amber-colored spring spores (pro-mycelium spores). These latter germinate very readily in a film of water on a glass, as illustrated at H, and produce a fine tube of mycelium.

In nature the black winter spores germinate upon straw as it decays on the ground in spring, and the minute, ovoid, pale amber-colored spores are carried about in the air in millions. But—and this is the most important fact to know—they can not enter into the tissues of cereals and grasses, but have to pass through those of another plant, a plant luckily not growing wild in our state, and only cultivated here and there for the sake of ornament and the berries it produces. The spring spores will only grow in the barberry and some allied plants. This has been proved over and over again. At least up to the present time no

other plants, and certainly not cereals and grasses, are known in which the spores can grow.

As soon as such spores reach the leaf of a barberry plant they sink into it through the cells of the epidermis to the body of the leaf. *They do not pass through the mouths or stomata.* In the leaf they produce a fungus of an apparently entirely different character from that on the wheat, viz., the Barberry Blight (*Æcidium berberidis*) shown in Fig. 9.

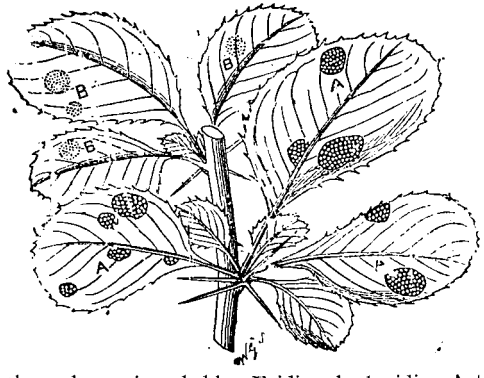


FIG. 9. Barberry leaves invaded by Æcidium berberidis. Actual size.

The Barberry Blight is very common upon this plant wherever it is grown in Minnesota. The parasitic æcidium almost invariably grows on the under surface of the leaves, although it is sometimes also found on both sides, in fact upon all parts of the plant. It is shown in Fig. 9 at *A, A, A,* where it forms clusters of groups of little sulphur-colored spots imbedded in dark red or swollen patches. If we study the upper surface of the leaves, we find similar patches more or less covered with little black dots termed *spermogones.* These are shown at *B, B, B.* These *spermogones* also occur, but only rarely, upon the lower surface. Each of them is very much smaller than the point of a pin, and on this account they are easily overlooked; they usually appear before the æcidium cups. If we study both with a strong magnifying lens the

spermogones still look like small black spots, but if we observe the æcidium clusters we see companies of beautiful sulphur-yellow cups bursting open through the lower surface of the leaf, and each cup is filled with a yellow powder resembling small yellow grain. To understand clearly the nature of these cups or of the black spermogone spots it is necessary to cut a section through the barberry leaf, as in Fig. 10. A represents the lower, B the

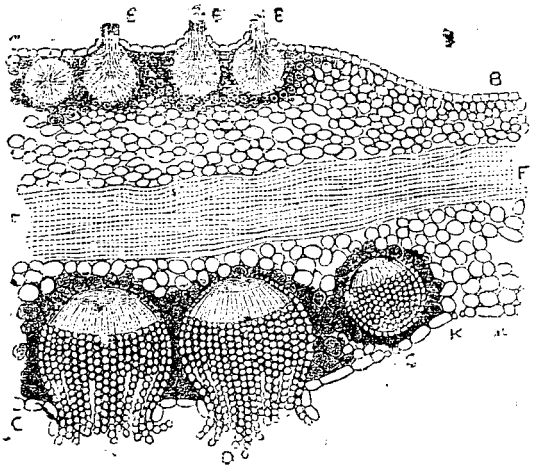


FIG. 10. Section through a barberry leaf, showing the cups below and the spermogones above. Enlarged 50 diameters.

upper surface of the leaf, at C one of the little cups is still buried in the tissues of the leaf. At DD two of the mature cups are shown, and at EEE three black spermogones; leaves invaded by this fungus are greatly thickened, as may be seen at GH. If we enlarge such a section still more we can observe the details, still better shown in figs. 11 and 12. In fig. 11 a section through a cup of *æcidium berberidis* is shown. The lower skin at B is ruptured by the fungus from within at CD. The fine, almost granular mycelium from which the fungus springs is shown at the top at D. It creeps amongst the intercellular spaces at E. The outer coat of the cup, consisting of a single layer of transparent, five-sided cells, is shown at FF, and the sulphur-yellow spores

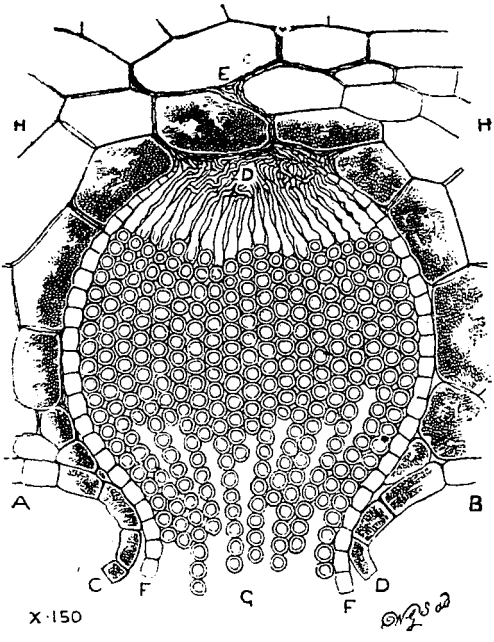


FIG. 11. Section through a cup of *Æcidium berberidis*. Enlarged 150 diameters.

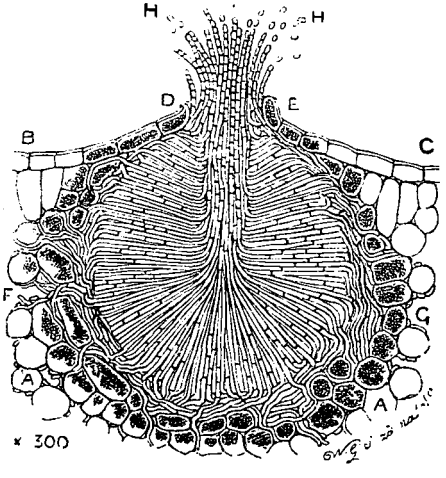


FIG. 12. Section through a *Spermogonium*. Enlarged 300 diameters.

hanging in chains from the open cup, at G. These spores drop as soon as ripe, and others, which are continuously produced, take their places.

A similar action takes place in the spermogonia upon the upper surface of the leaf. Here the mycelium gradually approaches the upper surface through the intercellular spaces. When near the surface it forms minute knots, similar to the cups upon the under surface of the leaf, but differing in an important particular, i. e., the æcidium cup grows from the base of the spermogonium by a constant protrusion of new threads from the circumference to the center. The spermogonium, which means a flask or case containing *spermatia,* contains large numbers of these extremely minute bodies, which possess the functions of pollen in higher organized flowers. A ripe spermogonium is shown in Fig. 12, and a single æcidium spore in Fig. 13. Attached to it are four sperm-

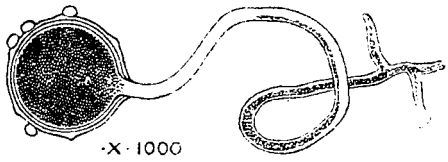
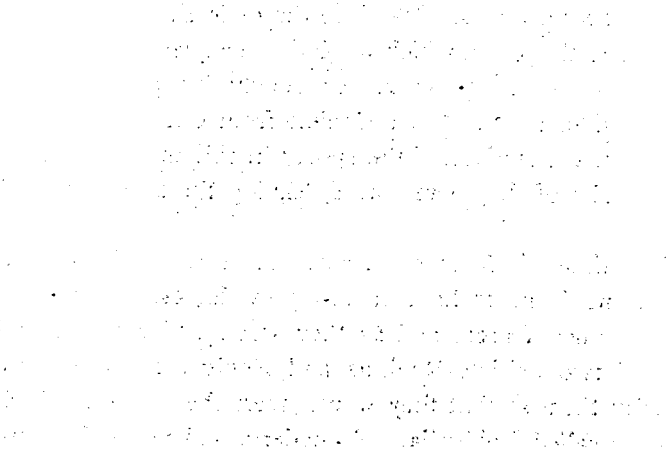


FIG. 13. Germinating spores of *Æcidium Berberidis.* Enlarged 1000 diameters.

atia from the spermogones. They are the male element, and are grains similar to the pollen which we find so frequently glued to a stigma. These spores grow rather slowly by protruding a mycelial thread in a convoluted fashion from one of about six weak spaces on the surface of the spore; in this mycelial thread the vital material of the spore enters, leaving the latter dry and empty.

In ancient times diseases caused by rust seem to have been widely distributed and to have caused great losses. They were consequently much feared, and as they stood under the special protection of two deities, Robigus and Robigo, festivals were held to pacify them so that they would avert the disease. Such festivals were called Robigalia. A modern, and no doubt more

successful way to partly prevent injuries caused by rusts, but especially by the Black Rust or Summer Rust, is to prevent the latter from wintering in our state. And to do so is not very difficult. All that is necessary is to permit no barberry to grow anywhere near the grain fields. The experience of last season has clearly demonstrated the fact that barberries communicate the Black Rust to the wheat, and that neighborhoods in which these plants are permitted to grow are always badly infested by this disease, more than any other place, and that the disease spreads from such centers to the whole region. By destroying such breeding places of the Black Rust we do not entirely prevent this disease, but our fields will not be infested by it early in the season, and only much later from spores coming with the wind from the south. Every farmer should insist upon this: *Never permit barberries to grow near a grain field.*



THE HESSIAN FLY.

OTTO LUGGER.

This destructive insect has again caused considerable losses to the farmers of Minnesota, and seems to have found a permanent home in the western counties, extending from Jackson, Cottonwood and Pipestone counties in the south to the entire Red River Valley in the north. Even parts of Manitoba have been invaded. It has been especially injurious in the Red River Valley, causing losses from 5 to 25 per cent on many farms. A large area is again badly infested, and, what is worse, there seem to be but very few parasites to assist us against this enemy. It seems that the abundant rains early in spring assisted this insect very materially, as it is a being that loves cold and wet seasons, and not like the equally destructive chinch bug, dryness and warmth. The damage in many places was quite serious, and close attention on the part of farmers is required to prevent still more serious losses in the future.

The history of the Hessian Fly (*Cecidomyia destructor* Say) in more southern and eastern regions of the United States is briefly as follows: There are ordinarily two broods or generations, which appear during May and June, and later during September and October. . The fly is a small, two-winged insect, resembling somewhat a mosquito, dusky in color, and about one-eighth of an inch in length. The male is very slender, and the female, when ready to deposit her eggs, a little stouter. The eggs, oval and bluntly pointed at each end, are about one-fiftieth

of an inch long, and of a dull reddish color. They are laid singly, or two or three in a cluster, on the upper surface of a leaf. Some years ago a female fly, just leaving the puparium, was dissected, and 238 eggs were found in her, which shows how rapidly this pest can increase if conditions are at all favorable. As soon as the young white maggot hatches, it works its way downward inside the sheaths to feed upon the succulent tissue at the base of the stalk. In the autumn they usually go beneath the surface of the soil, but in the spring more often stop just above the surface, at or near the lower joints. The larvæ, or maggots, feed there until ready to change to the pupa or flax seed stage, which is assumed between the sheath and the stem. The flax seed stage takes its name from the great resemblance between the puparium and the seed of flax in size, color and form. This little seed-like object is nothing but the old skin of the maggot shrunken, hardened and colored brown; it contains the true pupa, from which issues the perfect fly at one of the periods mentioned before. The presence of the puparium, or "flax-seed," can usually be detected by the breaking down of the stem at the point where it is found. This breaking down is due to the weakening of the stem, which has its interior partly destroyed by the maggot; and as this takes place at about the time that the ear of wheat forms, and before harvest, nearly all the infested stalks remain on the ground, not being cut by the harvester; and the presence of the fly is at this time noticed even by non-observant farmers. As the maggots and the flax-seeds are not readily detected except by a careful search with a knife, the numerous uncut straws upon the ground are frequently explained by the occurrence of a slight hailstorm, lack of silicate in the straw, too much moisture, or by what not.

The different stages of the Hessian fly are shown in Fig. 14.

The insect is double brooded in more southern places, but there may be adult individuals found at any time between the two broods, not, however, in great numbers. Such individuals mature in wheat sown out of season, or else in volunteer wheat.

In more southern states the following remedies are of value:

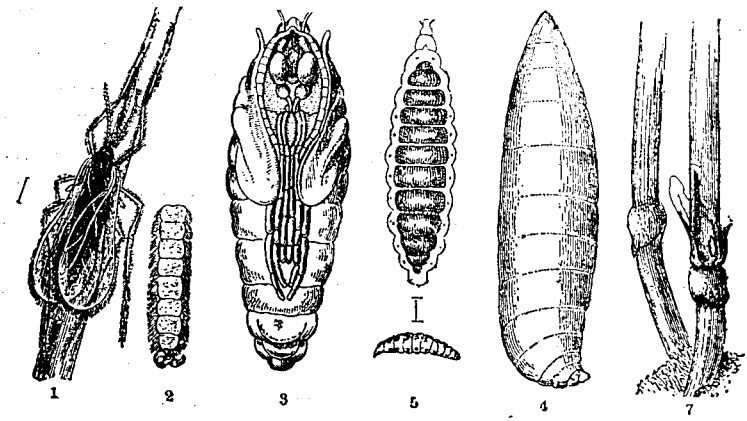


FIG. 14. Hessian Fly. 1, adult female; 2, male abdomen; 3, pupa removed from flax seed; 4, flax seed; 5, larva or maggot; 7, flaxseed in position. All enlarged with the exception of 7.

They are here simply given as furnishing suggestions to our farmers:

Late Sowing of Fall Wheat—This furnishes the fall brood, which issues in September and early October, nothing upon which to deposit its eggs, or if deposited, it is too late for the larvæ to burrow to a safe place in the stem to pass the winter.

Burning the Stubbles has been found to destroy many of the maggots and the "flax-seeds."

Rotation of Crops often leaves the adults without wheat plants on which to deposit eggs, so that when wheat is again sown the flies are all dead in that vicinity. It is a process of starving them out.

Pasturing Early Sown Wheat in the Fall is likely to destroy large numbers of maggots and "flax-seeds."

The Hessian Fly is now common almost throughout the western portion of our state, and not alone in the more southern counties, where both winter and spring wheat is grown. It is most abundant, however, in the Red River Valley, where only spring wheat is grown, and it is difficult to understand how this insect can exist under such conditions. If it was single-brooded

an explanation would be simple, and it almost seems as if this was the case, as the writer has thus far not been able to obtain winged flies from puparia collected early in September, with a single exception, as one Hessian-fly issued Aug. 22 from infested straw obtained from St. Hilaire, Minn. Immense numbers of puparia from many parts of the state have been kept under the most suitable conditions in breeding-cages, glasses, boxes, etc., etc., yet only one fly issued, besides numerous parasites. This seems to indicate that the flies do not usually issue during the autumn, but remain in the straw until spring. Another observation, though not a proof that there is no fall brood, is the fact that no larvæ or puparia could be found in volunteer plants of wheat growing near fields which had been badly infested.

It is very important to know in what condition the Hessian fly winters. If in the "flax-seed" stage, which seems to be the case, then a remedy is very simple and inexpensive. The insect being found in the first joint of the stem, or very near it, is in that portion of the plant that remains in the stubble field, or is not carried away in the bundles. Hence the insect can be destroyed with the stubbles. In some cases it is possible, by cutting the plants in such a manner that combustible material is left, to burn over the field, and thus destroy all the intruders. But if this can not be done *plowing* is an excellent remedy. This should be done as soon as possible after harvesting. The flies, even if they should issue during September or October, can not reach the surface of the plowed fields, as they are weak and unable to penetrate a thickness of several inches of soil. They are kept prisoners and have to perish. The parasites, however, which may be found in some of the puparia, have but little difficulty of escaping, hence plowing at the proper time, i. e. soon after harvesting, will destroy our enemies and protect our friends.

The Hessian fly is the prey of many parasites, and in 1896, when this noxious insect first caused serious injury in Minnesota, these beneficial insects helped to such an extent as to almost stamp out the intruders. The many specimens of infested straw received this autumn do not reveal the presence of many parasites

and only straw obtained from near Crookston contained some. Of course more parasites will be at work than could be decided from the material received, but the outlook is by no means as hopeful as it was in 1896; hence farmers should not depend upon the assistance of parasites, but should assist themselves by plowing all stubble fields as soon as ever they can, and especially those that they know contained Hessian flies and Frit flies.

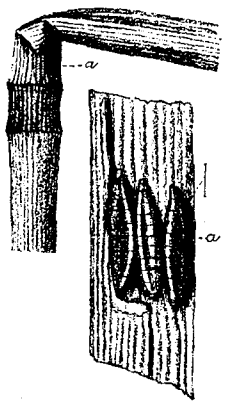


FIG. 15. Hessian Fly. At the right, three puparia (*a*) exposed; at the left, puparium (*a*) and the manner in which straws bend and break. Enlarged. Original.

As many farmers have never seen the "flax-seeds" the illustration (Fig. 15) has been prepared, which will assist them to detect their hidden foe.

In the following illustrations those parasites are shown which are at present most numerous and of great assistance. They are all very minute, and not apt to be seen. But those interested in such matters can easily decide for themselves whether such parasites are present or not. All they have to do is to keep a few pieces of straws containing the "flax-seeds" of the Hessian flies in a bottle. If parasites are present they soon show themselves by eating round holes from the infested flax-seeds to the outside of the straws, and they can be seen as dark and very active minute

objects, constantly running about as if in search of new enemies to conquer.

Three different species of parasites have been observed thus far. Two of the adult parasites are shown in the illustrations.

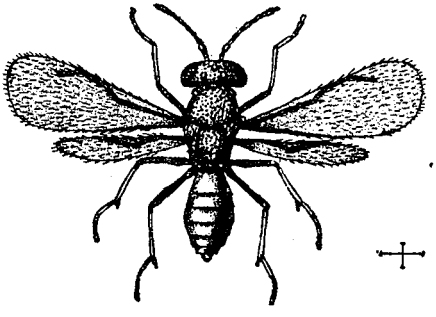


FIG. 16. Female of *Merisus destructor*, Lag. Enlarged. Original.

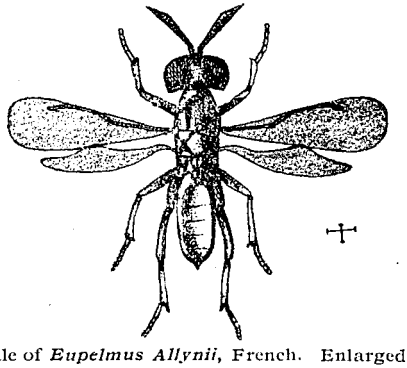


FIG. 17. Male of *Eupelmus Allynii*, French. Enlarged. Original.

Fig. 16 represents a female of the most common parasite (*Merisus destructor* Say), and Fig. 17 the male of *Eupelmus allynii* French). The female of the latter occurs both with and without wings. A third parasite (*Polygnotus hiemalis* Forbes) was also raised. It is very small, and six of these minute beings found sufficient food to pass through all their metamorphoses in a single puparium of the Hessian fly. In Fig. 18 is shown the broken off

FIG. 18. Puparium of Hessian fly, with six cocoons of a parasite. Enlarged. Original.

culm, the puparium of the Hessian fly, and the six small cocoons of this minute parasite still fastened to it.

MIGRATORY LOCUSTS OR GRASSHOPPERS.

OTTO LUGGER.

It is well known to all farmers and others engaged in growing grain, vegetables and fruit, that locusts are among the worst enemies they have to combat, and especially the migratory kinds, as these usually occur in vast armies. Our state is so situated that armies of such devouring insects can be expected from time to time, and it is well to be always prepared for such a visit. This is especially true at this time, when two of the worst kinds, the Rocky Mountain Locust (*Melanoplus spretus,* Uhl.) and the Lesser Migratory Locust (*Melanoplus atlanis,* Ril.), have already reached our state in small swarms. The former, if not actually in the state in large numbers, is very close to it. The latter is distributed over many portions of the state and a third, the *Cammula pellucida* Scudder, seems to be also coming from the Northwest. None of them have as yet caused much damage to our crops, but may do so next year if no steps are taken to prevent it. Many of our common native species have also become very numerous, and have caused considerable damage in isolated cases.

In the First Annual Report of the U. S. Entomological Commission we can find an excellent description of the destructive power of locusts, and many of our farmers know to their cost how correct this description is. No one who has not witnessed the ravaging power of locusts can fully conceive of or appreciate it. The organization and habit of the typical locust admirably fit it for ravenous work. Muscular, gregarious, with powerful jaws,

and ample digestive and reproductive systems; strong of wing and assisted in flight by numerous air sacs that buoy—all these traits conspire to make it the terrible engine of destruction which history shows it to have been under conditions favorable to its excessive multiplication. Insignificant individually but mighty collectively, locusts fall upon a country like a plague or a blight. The farmer plows and plants. He cultivates in hope, watching his growing grain, in graceful, wave-like motion wafted to and fro by the warm summer winds. The green begins to golden; the harvest is at hand. Joy lightens his labor as the fruit of past toil is about to be realized. The day breaks with a smiling sun that sends his ripening rays through laden orchards and promising fields. Kine and stock of every sort are sleek with plenty, and all the earth seems glad. The day grows. Suddenly the sun's face is darkened, and clouds obscure the sky. The joy of the morn gives way to ominous fear. The day closes, and ravenous locust-swarms have fallen upon the land. The morrow comes, and oh! what a change it brings! The fertile land of promise and plenty has become a desolate waste, and old Sol, even at his brightest, shines sadly through an atmosphere alive with myriads of glittering insects. Falling upon a cornfield, the insects convert in a few hours the green and promising acres into a desolate stretch of bare, spindling stalks and stubs. Covering each hill by hundreds; scrambling from row to row like a lot of young famished pigs let out to their trough; insignificant individually, but mighty collectively, they sweep clean a field quicker than would a whole herd of hungry steers. Imagine hundreds of square miles covered with such a ravenous horde, and one can get some realization of the picture presented in many parts of the country west of the Mississippi during years of locust invasions. Their flight may be likened to an immense snow-storm, extending from the ground to a height at which our visual organs perceive them only as minute, darting scintillations, leaving the imagination to picture them indefinite distances beyond. It is a vast cloud of animated specks, glittering against the sun. On the horizon they often appear as a dust tornado, riding upon

the wind like an ominous hail storm, eddying and whirling about like the wild, dead leaves in an autumn storm, and finally sweeping up, to, and past you with a power that is irresistible. They move mainly with the wind, and when there is no wind they whirl about in the air like swarming bees. If a passing swarm suddenly meets with a change in the atmosphere, such as the approach of a thunder storm or a gale of wind, they come down precipitately, seeming to fold their wings, and fall by the force of gravity. At other times, in alighting, they circle in myriads about you, beating against everything animate or inanimate; driving into open doors and windows; heaping about your feet and around your buildings; their jaws constantly at work biting and testing all things in seeking what they can devour. In the midst of the incessant buzz and noise which such a flight produces, in the face of the unavoidable destruction everywhere going on, one is bewildered and awed at the collective power of the ravaging host, which calls to mind so forcibly the plagues of Egypt. The noise their myriad jaws make when engaged in their work of destruction can be realized by any one who has fought a prairie fire, or heard the flames passing along before a brisk wind, the low crackling and rasping—the general effect of the two sounds is very much the same. Nothing, however, can surpass the prophet Joel's account of the appearance and ravages of these insects.

> "Onward they come, a dark, continuous cloud
> Of congregated myriads numberless,
> The rushing of whose wings was as the sound
> Of a broad river, headlong in its course
> Plunged from a mountain summit, or the roar
> Of a wild ocean in the autumn storm,
> Shattering its billows on a shore of rocks."
>
> —*Southey.*

As a full account of the three species has been given in a number of bulletins, some of which can still be had by applying for them at the office of the Experiment Station in St. Anthony

Park, it is not necessary to repeat it here. The three kinds, as well as two of our most common and destructive native kinds, have been illustrated in Plates III and IV, as well as in the text, so that a little study of these illustrations will enable our farmers to make certain which of these enemies they have to combat.

At the present time only one remedy can be applied, which depends entirely upon the way in which these locusts deposit their eggs, and for this reason a chapter printed in the 3rd Annual Report of the Entomologist is repeated.

HOW LOCUSTS DEPOSIT THEIR EGGS.

It is very important to know the manner and localities in which eggs are laid by the different kinds of locusts, because the only true and always successful remedy depends almost entirely upon this knowledge. In former papers the method of laying eggs by the Rocky Mountain Locust was discussed, but it is best to repeat and enlarge upon what was written at that time. The following figures will illustrate the method of egg-laying better than words. The holes for the reception of the eggs are made by means of two pairs of horny valves at the tip of the

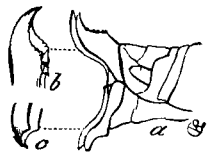


FIG. 20.—Rocky Mountain Locust—*a*, anal characters of female showing horny valves, b, and c. (After Riley).

abdomen of the female (Fige. 20, *b* and *c*). These open and shut rapidly, and are well adapted to execute this function. The female, pressing the tip of her abdomen forcibly against the soil, rapidly opens and shuts these hard and pointed valves, and soon pushes them into the ground, thus drilling a hole. Fig. 21 illustrates this action, and the various positions assumed by the females are plainly indicated. In a short time nearly the entire

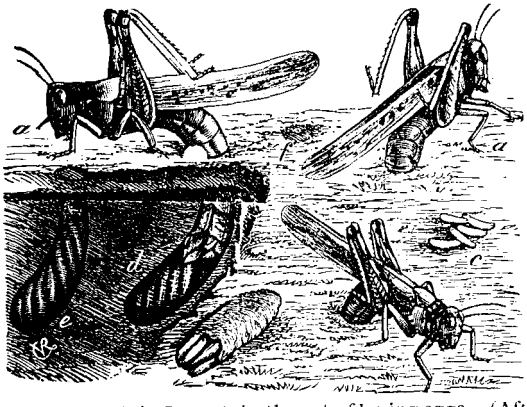


FIG. 21.—Rocky Mountain Locust, in the act of laying eggs. (After Riley.)

and greatly extended abdomen is inserted in a little curved and more or less oblique cavity. The legs are hoisted above the back during the operation of drilling this hole, which requires more or less time, depending entirely upon the condition and character of the soil. As soon as the hole is finished, it is filled with a frothy and mucous material. Professor Riley, in describing the method of laying eggs, writes: "By repeatedly extracting and studying specimens in every stage of oviposition, we have been able to ascertain the exact method by which the egg-mass is formed. If we could manage to watch a female from the time the bottom of her hole is moistened by the sebific fluid, we should see the valves all brought together, when an egg would pass down the oviduct along the ventral side, and, guided by a little finger-like style, pass in between the horny valves, and issue at their tips amid the mucuous fluid already spoken of. Then follows a period of convulsions during which more mucous material is elaborated, until the whole end of the body is bathed in it, when another egg passes down and is placed in position. These alternate processes continue until the full complement of eggs are in place, the number ranging from twenty to thirty-five, but averaging about twenty-eight. The mucous matter binds all the eggs in a mass, and when the last is laid, the mother devotes some time to filling up the some-

what narrower neck of the burrow with a compact and cellular mass of the same material, which, though light and easily penetrated, is more or less impervious to water, and forms a very excellent protection. When fresh the mass is soft and moist, but it soon acquires a firm consistency."

To a casual observer the eggs of our locust appear to be thrust indiscriminately into the hole made for their reception. A more careful study of the egg-mass, or egg-pod, will show, however, that the female took great pains to arrange them, not only so as to economize as much space as possible, consistent with the form of each egg, but so as to best facilitate the escape of the young locust; for if, from whatever cause, the upper eggs should fail to hatch, or should hatch later than the lower ones, the former would offer an impediment to the exit of the young in their endeavor to escape from these last, were there no provision against such a possibility. The eggs are, indeed, most carefully placed side by side in four rows, each row containing seven. They oblique a little cross-wise of the cylinder (Fig. 22, *a*). The posterior, or narrow end, which issues first

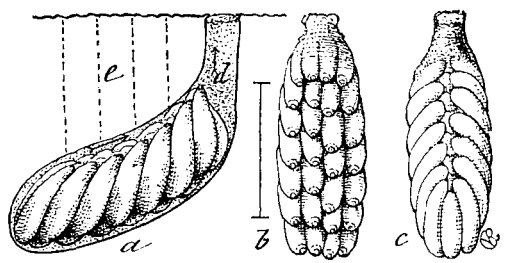


FIG. 22.—Egg-mass of Rocky Mountain Locust—*a*, from the side, within burrow; *b*, from beneath; *c*, from above; enlarged. (After Riley).

from the oviduct, is thickened and generally shows two pale rings around the darker tip (Fig. 22, *b*). This is pushed close against the bottom of the burrow, which, being cylindrical, does not permit the outer or two side rows to be pushed quite as far down as the two inner rows, and for the very same reason the upper or head ends of the outer rows are necessarily bent to the

same extent over the inner rows, the eggs when laid being somewhat soft and plastic. There is consequently an irregular channel along the top of the mass (Fig. 22, *c*), which is filled also with the same frothy matter that surrounds each egg, which matter occupies all the space in the burrow not occupied by the eggs. The whole plan is seen at once by a reference to the accompanying figure, which represents, enlarged, a side view of the mass within the burrow (*a*) and a bottom (*b*) and top view (*c*) of the same, with the earth which adheres to it removed.

Each female of the Rocky Mountain locust lays on an average about three egg-masses; this is done at intervals of two weeks, so that the egg-laying season extends through six to eight weeks.

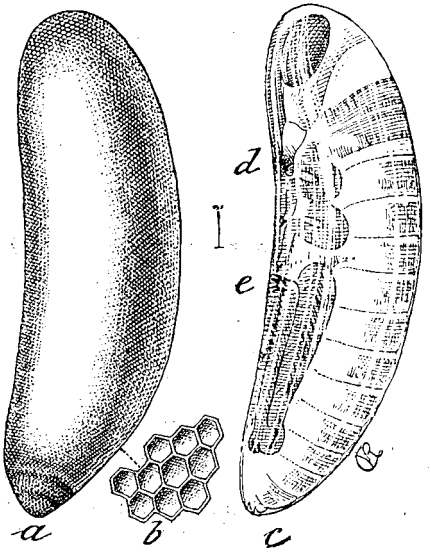


FIG. 23.—Egg of Rocky Mountain Locust—*a*, showing sculpture of outer shell; *b*, the same very highly magnified; *c*, the embryo, just before hatching. (After Riley).

The egg is surrounded by a shell consisting of two layers, of which the outer one is thin, semi-opaque, thus producing the creamy yellow color; highly magnified it appears (Fig. 23, *a*) densely and minutely pitted or rather marked by hexagonal

concavities (Fig. 23, *b*). The inner and thicker layer is deep yellow, smooth and translucent, so that the form of the embryo can be plainly seen when maturing inside. The outer layer is quite brittle, but the inner one very tough, requiring a strong pressure to rupture it. As the embryo within matures (Fig. 23, *c*), the egg-shell becomes weakened, and the egg plump and somewhat more transparent. By the muscular efforts of the enclosed insects, but chiefly by thorns arming the hind tibiæ, (Fig. 23, *e*), the shell is eventually broken, and the young locust pushes its way through the neck of the burrow towards the light.

Nearly all the eggs in a pod hatch at the same time, and the young escape through the small hole left for this purpose. When the young insect reaches the surface it is quite weak, and still surrounded by a very delicate film, which has to be first removed before the young locust can jump about. By contracting and expanding muscular movements this enveloping film splits along the middle of the back, near the head, and is gradually pushed backwards, remaining as a white crumpled pellet behind. At first pale and colorless, the young locust assumes its dark color in the course of an hour.

From this account of the hatching process, we can readily understand why the female in ovipositing prefers compact or hard soil to that which is loose. The harder and less yielding the walls of the burrow, the easier will the young locust crowd its way out.

Though the covering which envelops the little animal when first it issues from the egg is quite delicate, it nevertheless, in the struggles of hatching, undoubtedly affords much protection, and it is an interesting fact that while, as we have seen, it is shed within a few minutes of the time when the animal reaches the free air, it is seldom shed, if, from one cause or another, there is a failure to escape from the soil, even though the young locust may be struggling for days to effect an escape.

While yet enveloped in this pellicle, the animal possesses great forcing and pushing power, and if the soil is not too compact, will frequently force a direct passage through the same to

the surface, as indicated by the dotted lines (Fig. 22, *e*), but if the soil is at all compressed it can make little or no headway except through the appropriate channel (Fig. 22, *d*). While crowding its way out, the antennæ and four front legs are held in much the same positon as within the egg, the hind legs being generally stretched. But the members bend in every conceivable way, and where several insects are endeavoring to work through any particular passage, the amount of squeezing and crowding they will endure is something remarkable. Yet if by chance the protecting pellicle is worked off before issuing from the ground, the animal looses all power of further forcing its way out. The instinctive tendency to push upwards is also remarkable. In glass tubes, in which eggs were hatched in order to watch the young, these last would always turn their heads and push towards the bottom whenever the tubes were turned mouth downwards; while in tin boxes, where the eggs were placed at different depths in the ground, the young never descend, even when they were unable to ascend on account of the compactness of the soil above.

The above minute account of the manner in which eggs are laid, and how the young are enabled to reach the surface, plainly indicates one good method by which the hatching of the eggs may either be prevented entirely, or by which the young may be prevented from reaching the surface. By plowing the fields containing eggs of the Rocky Mountain locust, we perform two operations: first of all we remove the eggs from near the surface and cover them with five or six inches of soil; secondly, we invert the position of the hole containing the egg-mass, so that instead of its mouth pointing upwards, it now points downwards. At all events, the young insects are prevented from reaching the surface, if this becomes compacted by rain and snow. Consequently if we plow during autumn or soon after the eggs are laid we are safe; although if we plow in the spring with a normal amount of rain, we also effectually prevent their hatching. Plowing has this additional advantage: the egg-masses in many cases are thoroughly broken up, the individual eggs become sur-

rounded by earth and moisture, and being no longer protected by the water-proof coat of dried mucous matter, they soon rot and perish.

The Lesser Migratory Locust lays its eggs in essentially the same manner. It always prefers, however, old stubble fields, bare spots in timothy fields, and neglected and dry pastures. In other words, well drained spots free of vegetation, and consequently soils free of roots, are preferred.

The Pellucid Locust has, in Minnesota, different habits as far as egg-laying is concerned. In the Western States it deposits eggs exactly like *spretus* and *atlanis*. The females of the Pellucid Locusts commence to deposit their eggs about the end of July, usually at least fourteen days later than the other migratory kinds. Their method of doing so is entirely different. As a general rule they select for this purpose pasture land, road sides, or, by preference, clearings from which the stumps have not yet been removed, although the land has already been used for crops. In such places large numbers of eggs are deposited in the sod. Usually they are placed right upon the surface of the soil, where they are protected by the grass and by the rubbish found in such situations (Fig. 24, *b* and *c*). Occasionally the eggs are deposited just beneath the surface, but only where the ground is sufficiently loose to enable the insects to do so. The eggs are about 4 mm. in length, and 1 mm. in diameter: they are slightly curved and rounded at the ends (Fig. 24, *a*). They are deposited in layers, each with three or four eggs, which overlap and appear somewhat irregular (Fig. 24, *b*). These diagonally overlapping layers are built up until an elongated cylindrical mass from 10 to 15 mm. in length is formed. This whole mass of eggs is protected by a water-proof covering composed of bits of earth cemented together with the frothy material produced by the mother insect at the time the eggs are deposited and arranged by her. One end of this protective layer of waterproof material is very thin, almost or entirely open, thus affording the young and weak locust an easy means of egress. Each cylindrical capsule contains about twenty eggs.

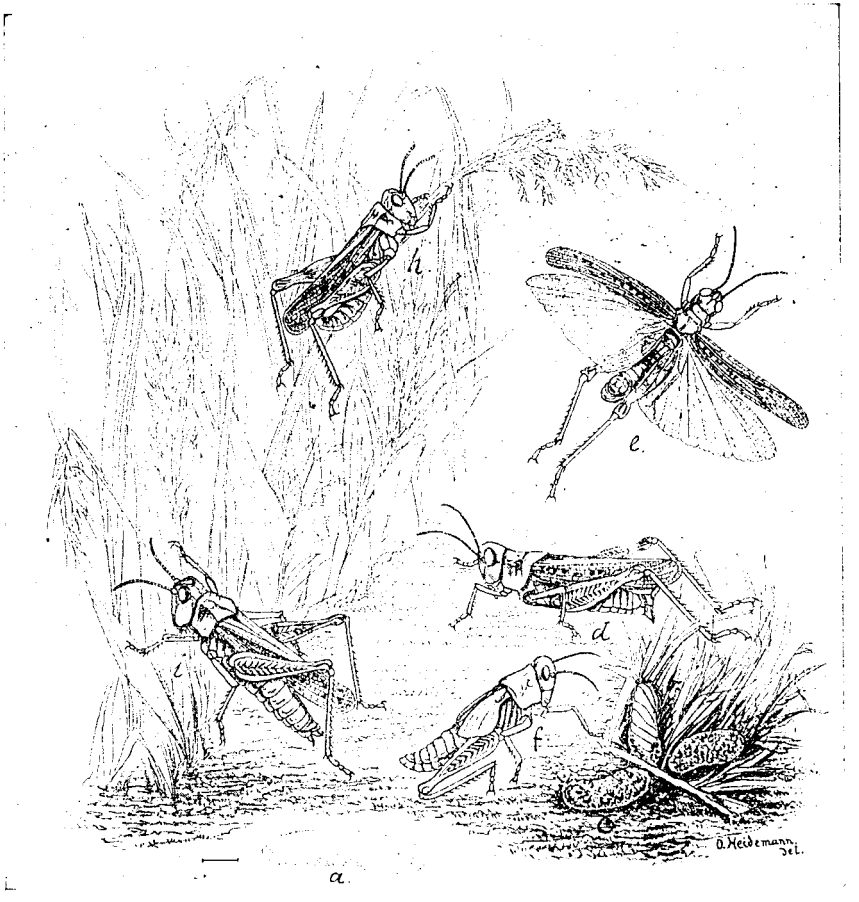


FIG. 24.—*a*, single egg of Pellucid Locust; *b*, egg-mass opened to show eggs inside; *c*, egg-mass; *i*, female; *h*, male. Lesser Migratory Locust; *d*, female; *e*, male; *f*, pupa. Natural size. Original.

Fig. 24 shows the Pellucid Locust and its eggs; also the Lesser Migratory Locust.

To distinguish with absolute certainty the three closely allied species *M. spretus, atlanis,* and the common native Red-legged locust (*M. femur-rubrum*) it is necessary to study the swollen abdomen of the males. Here we find constant differences, not

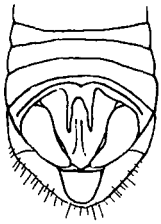


FIG. 27.

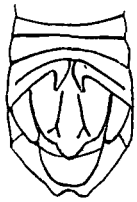


FIG. 26.

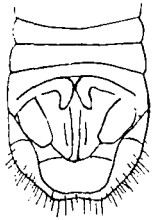


FIG. 25.

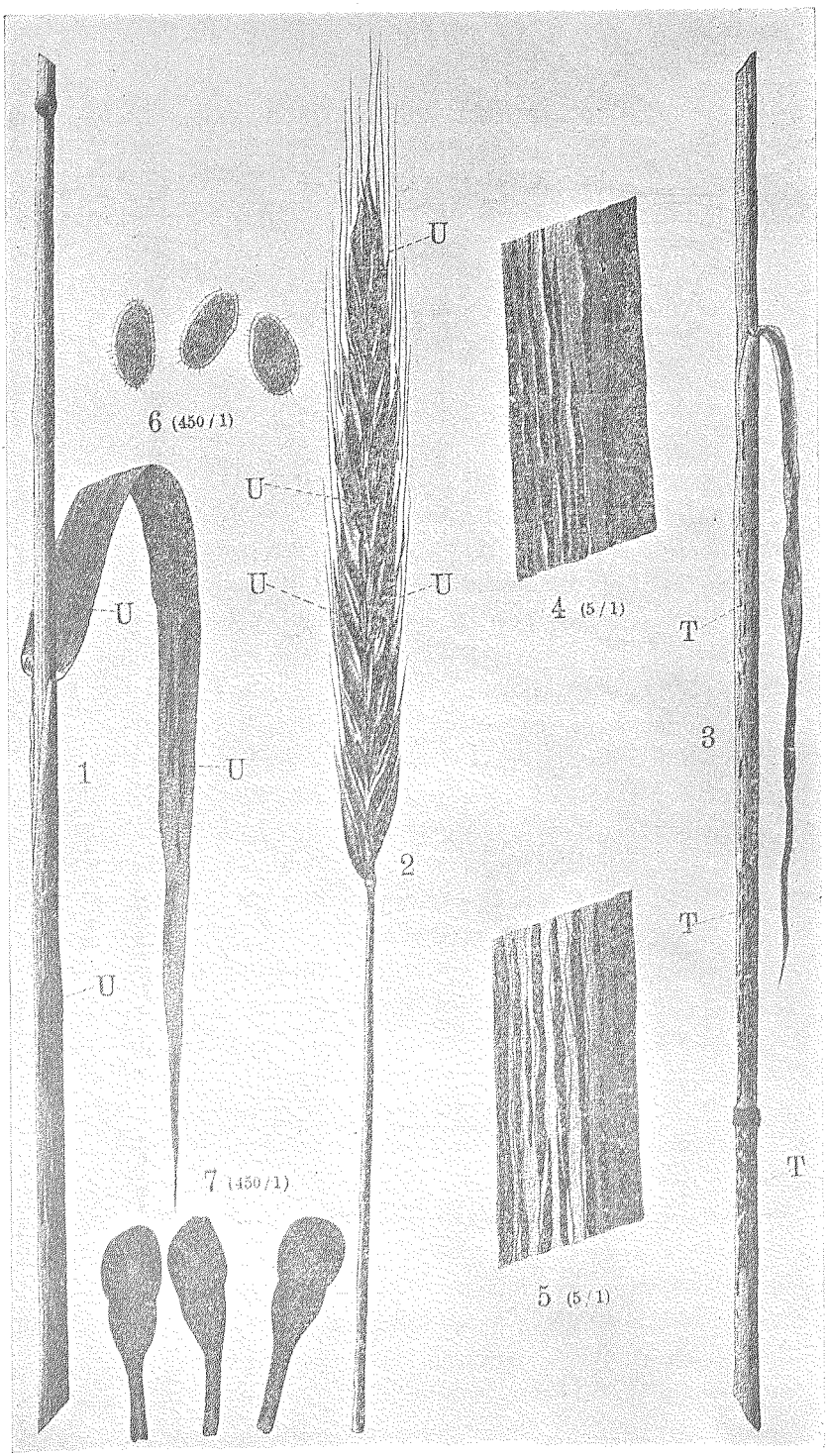
readily expressed in words. The illustrations show them very plainly. Fig. 25 illustrates the abdomen of *M. spretus*, Fig. 26, that of *M. atlanis*, and Fig. 27 that of *femur-rubrum*. It will be noticed that the two former ones have a decided notch at the tip. The females do not possess the peculiar knob-like ends of the abdomen, but have instead a pointed tip with four small and horny points used to drill a hole in the ground for the reception of eggs.

If we desire to get rid of the migratory species of locusts it is absolutely necessary to plow every inch of the cultivated ground, and especially the stubble-fields, which are invariably selected by the locusts for the purpose of egg-laying.

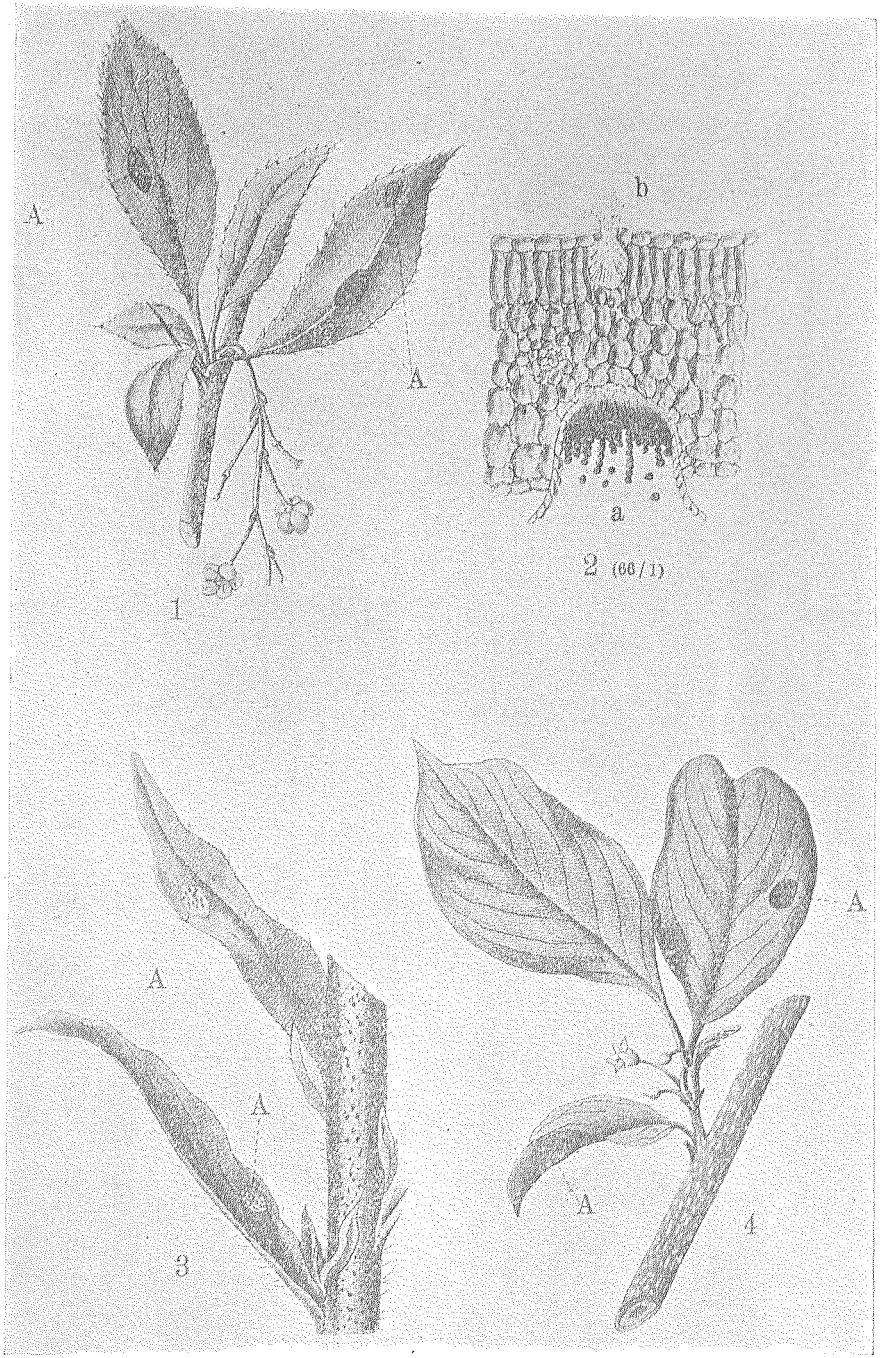
There are many other remedies that can be employed to kill these injurious insects, but not at the present time, and none are as effective as the one given.

Plate III and IV show the different kinds of locusts mentioned before.

PLATE I.

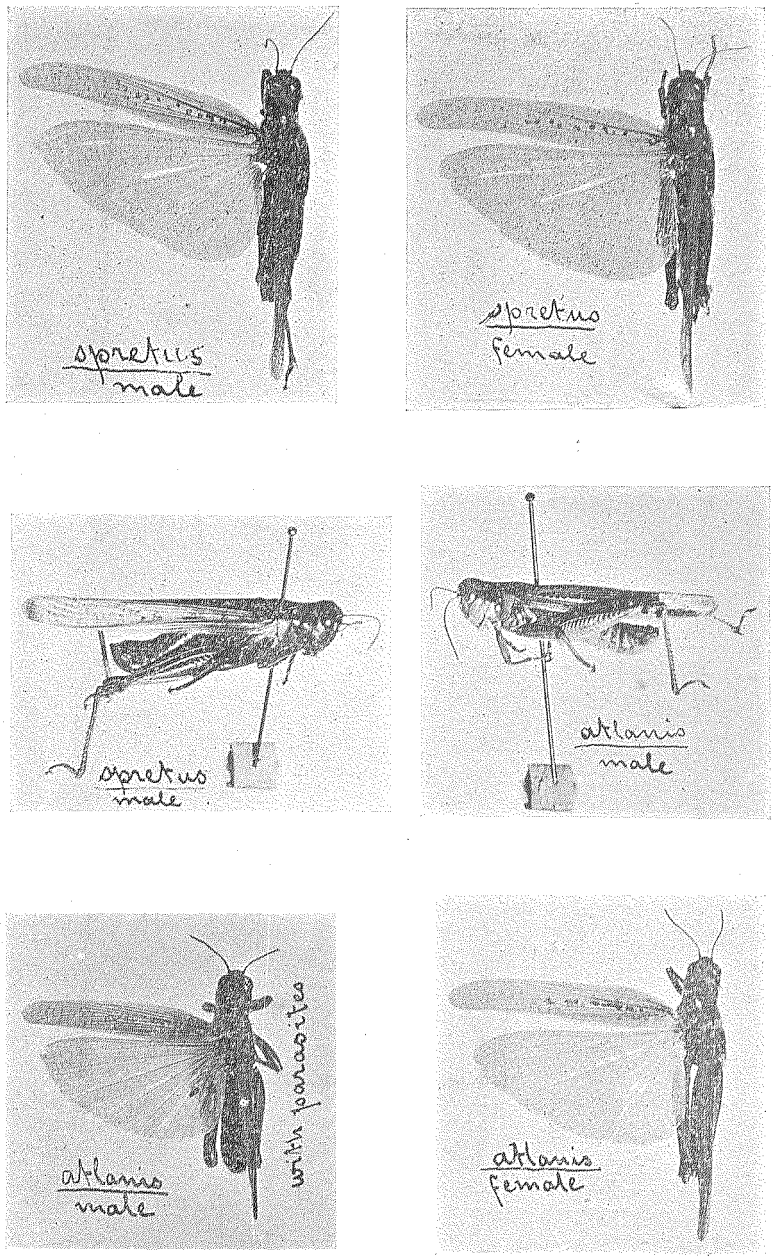


1. Rye plant, showing pustules (*sori*) containing red summer spores or uredospores (*UU*), natural size; 2, ear of rye with same, natural size; 3, pustules containing black winter spores or teleutospores (TT), natural size; 4, red uredospores, enlarged five diameters; 5, black teleutospores, enlarged five diameters; 6, three red uredospores, enlarged 450 diameters; 7, three black teleutospores, enlarged 450 diameters.



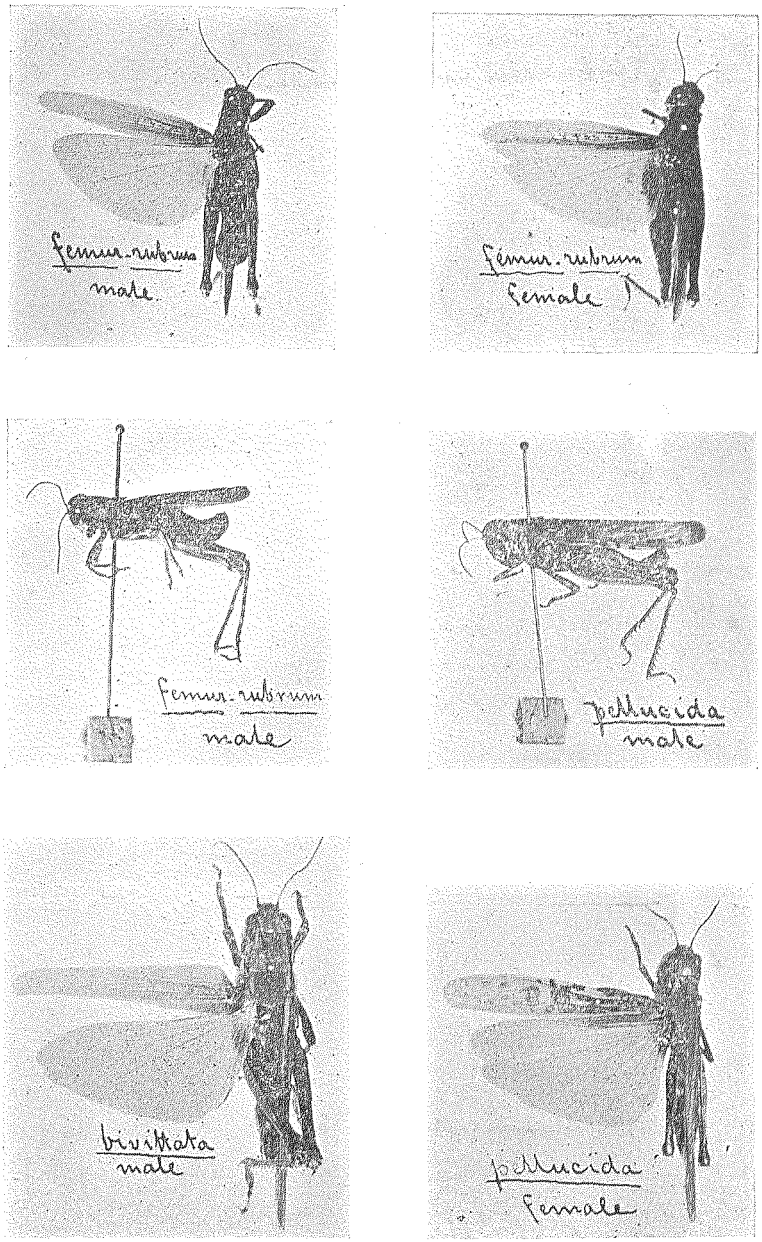
Æcidia, or Cups of Rusts. 1, AA of *Puccinia graminis*, Pers. (Black or Summer Rust), on leaves of barberry, natural size; 2, cross section through cup; *a*, cup with spores; *b*, spermogonium with spermatia, enlarged 66 diameters; 3, AA æcidia of *Puccinia rubigo vera*, Wtr. (Spring Rust), on Borage; 4, AA æcidia of *Puccinia coronata*, Cda. (Rust of Oats) on Buckthorn (*Rhamnus cathartica*); 3 and 4 natural size.

PLATE III.



Male and female Rocky Mountain Locust (*Melanoplus spretus*, Whl.) from above, and male of same from the side. The Lesser Migratory Locust (*M. atlanis*, Ril.) in same position. Enlarged about one-sixth.

PLATE IV.



Male and female Common Red-Legged Locust (*Melanoplus femur-rubrum*, De Geer) from above, and male of same from the side. The Pellucid Locust (*Camnula pellucida*, Scudder), male from side, female from above. The Common Two-Striped Locust (*Melanoplus bivittatus* Say.), female from above. Enlarged about one-sixth.

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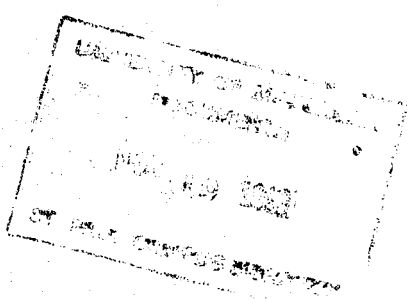
Rust.



13. Author Minnesota Bulletin 64.

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