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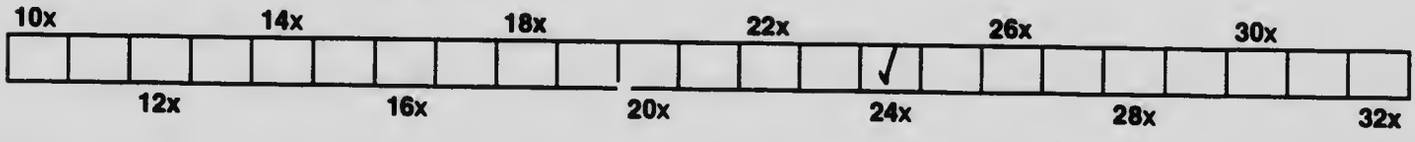

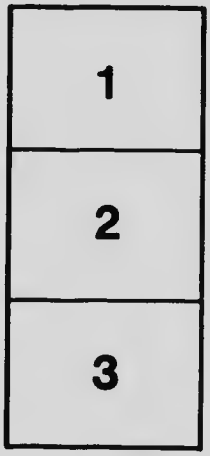

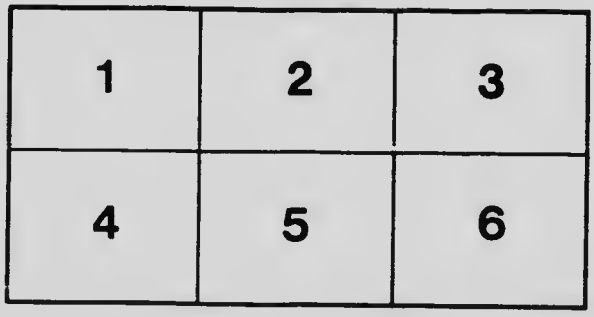

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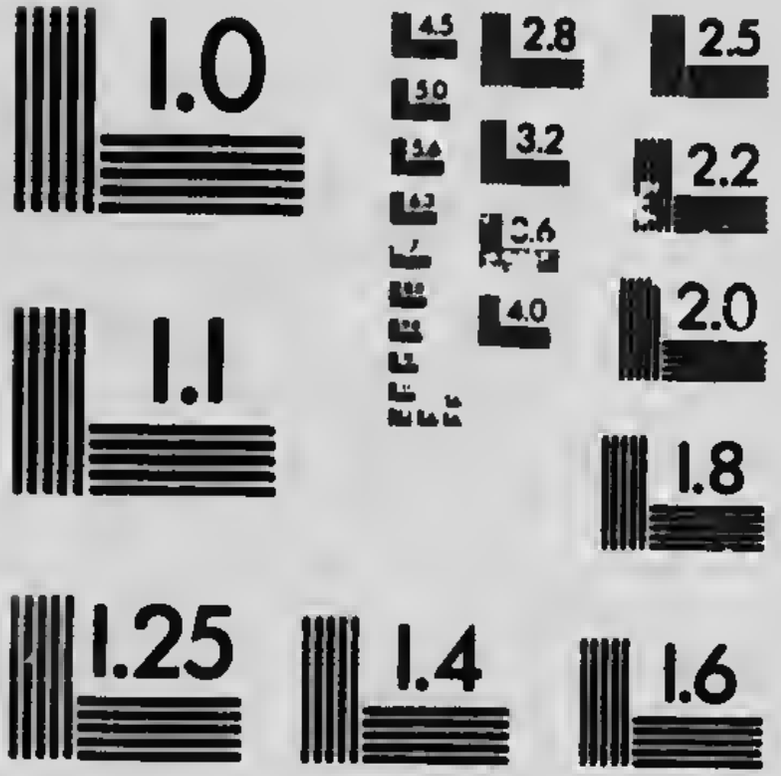

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Ontario Department of Agriculture

ONTARIO AGRICULTURAL COLLEGE

The Smuts and Rusts of Grain Crops

J. E. HOWITT AND R. E. STONE.

INTRODUCTION.

This bulletin is not written for the purpose of announcing new scientific discoveries concerning the smuts and rusts of grains, but with the object of making available to the general public, especially to the farmers of Ontario, the knowledge which scientific workers have accumulated regarding the nature and methods of control of smuts and rusts. With this object in view the writers have endeavored to discuss the subject in clear, simple, non-technical language, so that all who read the bulletin may readily understand it. It is hoped that this bulletin may serve to spread more widely information which will aid the farmers of Ontario in preventing loss from smuts and rusts. Special thanks are due to Prof. C. A. Zavitz and to Mr. W. H. Wright for their assistance.

LOSSES DUE TO SMUTS AND RUSTS.

It is exceedingly difficult, if not impossible, to estimate the financial loss caused by these diseases. The following rough estimate of the loss caused by smuts has been made by considering the value of the different grain crops grown in Ontario each year and the estimated annual average per cent. that the yield of the different crops is reduced by smut:

Oats.

Market value of the yearly crop, about $36,000,000.
Estimated average annual loss due to oat smut, 5 per cent. of crop.
Yearly financial loss $1,800,000

Wheat.

Market value of the yearly crop, about $16,000,000.
Estimated average annual loss due to smuts, 4 per cent. of crop.
Yearly financial loss $640,000

Barley.

Market value of the yearly crop, about $10,000,000.
Estimated average annual loss due to smuts, 2 per cent.
Yearly financial loss $200,000

Corn (Grown for husking.)

Market value of the yearly crop, about $8,000,000.
Estimated average annual loss due to corn smut, 1 per cent.
Yearly financial loss $80,000

Total yearly financial loss to the farmers of Ontario due to grain smuts..$2,720,000

The losses due to grain rusts are very hard to estimate as they vary very much with the season. Some years the loss may not exceed 2 per cent. of the grain crop, while other years it may exceed 10 per cent. Estimating the average annual loss at 4 per cent., and the yearly value of our grain crops, not including corn and rye, at $62,000,000, the yearly financial loss due to grain rust is $2,480,000.

These figures are but approximate, but they serve to impress the fact that the annual loss caused by smuts and rusts is very much larger than is generally realized.

This financial loss to the farmers of Ontario can be very much reduced. The grain smuts can be almost entirely prevented by proper treatment of the seed, and the loss caused by grain rusts materially reduced by skilful and careful farming.

The Cause of Smuts and Rusts of Grains.

The smuts and rusts of grains are fungus diseases; that is, they are caused by minute colorless plants, called fungi, which have lost the power of manufacturing their own food and have become thieves and parasites, stealing their food from other plants, and in so doing injuring them in various ways, thus causing what are known as fungus diseases. The bodies of the fungi which cause smuts and rusts of grain consist of fine, delicate threads or tubes (hyphæ) which are so exceedingly small that they can only be seen with the aid of a microscope. These live between the cells of the grain plants and obtain their nourishment from them. Some of these fungus threads (hyphæ) become changed and produce reproductive structures termed spores, which serve the same purpose as the seeds of flowering plants, viz: dispersal and reproduction.

In the case of the fungi which cause grain rusts the spores are produced in enormous numbers near the surface of the leaves or stems just beneath the skin (epidermis), which is finally ruptured, exposing the masses of spores, which are then easily seen on the leaves and stems as rusty red or black lines.

The spores of the smut producing fungi are usually formed in the ears or heads of the grain. The fungus threads (mycelium) attack the flowers when they begin to develop and feed upon the food being stored in the forming seeds. When this is exhausted, the fungus threads divide up into thousands of little spores. These compose the black smut masses so familiar to every farmer. The spores are exceedingly small; some idea of their size may be had by considering the fact that one smutted wheat grain contains between two and three million of them.

The spores of the smut and rust fungi are scattered by the wind, or by the threshing and handling of the grain in the case of some of the smuts. Each spore, if placed under proper conditions, is capable of producing its kind and finally causing again that particular smut or rust peculiar to the parent fungus.

KINDS OF SMUTS AND METHODS OF PREVENTION.

Loose Smut of Oats (*Ustilago avenæ* (Gers.) Jensen).

This is the commonest and most troublesome grain smut in Ontario. It is noticeable just as soon as the oats begin to head. It destroys the kernel, the hull and the chaff, changing them to a dark brown powder resembling soot, so that the

whole head becomes a mass of smut. These smut masses, which are composed of millions of spores, are blown away by the wind, leaving only the naked branches of the inflorescence.

LIFE HISTORY.—The spores are scattered by the wind about the time the oats are in flower. They are blown to healthy heads of oats, and lodge on the grain, probably getting inside the hull onto the kernel when the oats are in flower; here they remain dormant until the grain is sown. The disease is thus carried over the winter as spores on the grain. In the spring when the seed is sown and germinates, the same conditions, viz.: warmth and moisture, which cause the seed to germinate, also cause the spores to germinate. When they germinate, delicate fungus threads

FIG.—1. Loose smut of oats. (About one-half natural size.)

FIG. 2.—Stinking smut of wheat on left and loose smut of wheat on right. (About one-half natural size.)

are produced which penetrate the very young seedling plants. This is the only time that infection can take place. The fungus threads live inside the tissues of the oat plant, following the growing point up the stem, and, when the heads form, enter the young developing grains and floral structures, feeding upon the foods being stored in the ovules. These fungus threads, which are very abundant, finally divide up into numerous spores, converting the grains and chaff into a mass of smut.

TREATMENT.—Oat smut can be prevented by treating the seed with formalin. See directions for formalin treatment on pages 9 and 10. Bluestone should never be used for treating oats, as it injures the grain so that it does not germinate freely.

Wheat Smuts.

There are two common smuts of wheat in Ontario: stinking smut or bunt, and loose smut. It is very important that farmers should learn to distinguish between the two kinds, as stinking smut or bunt can be prevented by treating the seed with formalin or bluestone, while such treatment is of no use whatever in preventing loose smut. A little study will enable even a casual observer to distinguish between these two diseases.

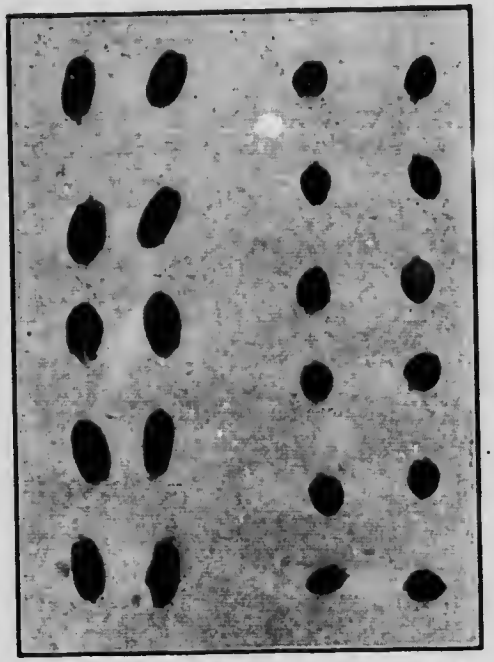

Fig. 3.—Bunted grains on left; sound grains on right. (About one-half natural size.)

Fig. 4.—Loose smut of wheat. (About natural size.)

Stinking Smut or Bunt of Wheat (*Tilletia foetens* (B. & C.) Trel.).

This is the commoner and more objectionable smut of wheat. It attacks only the grains, causing them to become short, plump, light in weight, and filled with a black, somewhat oily powder which has an odor like decaying fish. The chaff, while not destroyed, becomes bleached and distended, because of the swollen diseased grains within. When a bunted grain, "smut ball," is broken, the disagreeable odor of the powder within is very pronounced. Many of these "smut balls" are broken and the powder scattered in threshing and handling the grain and hence this smut, even in small quantities, can be detected by the odor which it imparts to the grain. Very small quantities of stinking smut render wheat unfit for milling purposes.

Life History.—The dark, ill-smelling powder in the diseased grains consists of numerous spores. It has been estimated that one "smut ball" may contain between two and three million spores. The "smut balls" are broken during

the threshing and handling of the wheat and the spores scattered among the sound grains to which they adhere. The disease is thus carried over as spores on the seed. When the seed is sown and germinates, the spores also germinate and produce delicate fungus threads, which enter the very young seedling plants. This is the only time that the fungus can gain entrance to the wheat plant. The fungus lives and grows inside the wheat plant, following the growing point up the stem and, when the heads begin to form, enters the young ovaries, feeding upon the foods, starches, etc., being stored in them. The fungus threads which fill the diseased ovaries finally divide up into countless spores which form the dark colored powder which fills the bunted grains.

TREATMENT.—Stinking Smut or Bunt of Wheat can be prevented by treating the seed either with formalin or bluestone. See directions on pages 9 and 10.

N.B.—If the seed wheat to be treated contains smut balls, they must be removed. This can be done with the fanning mill or by placing the grain, about a bushel at a time, in a tub of water, and stirring it. The smut balls, being light, will rise to the surface and can be skimmed off.

FIG. 5.—Spores of loose smut of wheat.
(Magnified many times.)

LOOSE SMUT OF WHEAT (*Ustilago tritici* (Pers.) Jens.).

This smut is more common and does more damage to wheat in Ontario than is generally supposed. It destroys both the grains and the chaff, changing them to a black powder. The whole head thus becomes a black smut mass. These smut masses are noticed in the field just as soon as the ears begin to form. They are very soon broken up and blown away by the wind, the only remaining evidence of the smut at harvest time being the naked central axis of the ear.

LIFE HISTORY.—The smut masses consist of millions of spores. These are scattered by the wind when the wheat is in flower. Some of these spores reach sound ears of wheat and drift in between the chaff on to the flowers. The spores germinate at once and produce delicate fungus threads ("germ tubes") which penetrate the developing grains. Once established inside the grain the fungus remains dormant. Infected grains are perfectly sound and there is no way of telling them from grains which are not infected except by skilful microscopic examination. The loose smut is thus carried over as the dormant fungus threads (mycelium) in the seed. On the germination of the seed the fungus threads begin to grow inside the germ and as the plant develops follow the growing point up the stem, finally invading the ears and chaff and reducing them to a mass of smut.

TREATMENT.—Loose Smut of Wheat *CANNOT* be prevented by treating the seed with formalin or bluestone If possible, secure seed from a district where Loose Smut is not present. Such seed will produce a crop free from this smut. If loose smut is bad and it is impossible to secure seed free from infection, it may be neces-

sary to establish a seed plot and treat the seed as directed in Jensen's modified hot water treatment, page 10.

SUMMARIZED COMPARISON OF STINKING AND LOOSE SMUTS OF WHEAT.

Loose Smut.	*Stinking Smut.*
1. Destroys both the grain and the chaff.	1. Destroys only the grain.
2. Has no disagreeable odor.	2. Has a very disagreeable odor.
3. Spores scattered by the wind at flowering time.	3. Spores scattered in the threshing and handling of the grain.
4. Carried over as the fungus threads (mycelium) inside the seed.	4. Carried over as the spores on the seed.
5. *Cannot* be prevented by treating the seed with formalin or bluestone.	5. *Can* be prevented by treating the seed with formalin or bluestone.

BARLEY SMUTS.

There are two kinds of barley smut, viz: Loose or Naked Smut of Barley, and Covered Smut of Barley. The former is the more prevalent and more serious disease in Ontario. It is very important that farmers should learn to distinguish these two smuts, as the covered smut can be prevented by treating the seed with formalin, while such treatment is of no use whatever in preventing the loose or naked smut.

LOOSE OR NAKED SMUT OF BARLEY (*Ustilago nuda* (Jens.) Kellerm and Swingle).

This is the smut which does most damage to barley in Ontario. It is very similar to loose smut of wheat. It destroys both the chaff and the grain, reducing them to a black powder resembling soot. This powder, which is in reality a mass of spores, is soon blown away by the wind so that at harvest time there is nothing left but the naked axis of the ear. See Fig. 6.

LIFE HISTORY.—The life history is similar to that of the fungus which causes loose smut of wheat. The spores are scattered by the wind when the barley is in flower. Some of them reach healthy ears of barley and drift in between the chaff on to the flowers. They germinate at once and produce delicate fungus threads (germ tubes) which penetrate the developing grains. Once established inside the grain the fungus soon becomes dormant. Infected grains are perfectly sound and there is no way of telling them from grains which are not infected except by very delicate and skilful microscopic examination. The fungus which causes loose or naked smut of barley is thus carried over as the dormant fungus threads (mycelium) inside the seed. On the germination of the seed the fungus threads commence to grow inside the germ, and, as the plant develops, follow the growing point up the stem, finally invading the flowers and chaff and reducing them to a mass of smut.

TREATMENT.—Loose or Naked Smut of Barley *CANNOT* be prevented by treating the seed with formalin or bluestone. If possible secure seed from a district where the smut is not found. Such seed will produce a crop free from the smut. If loose or naked smut of barley is bad and it is impossible to secure seed

free from infection, it will be necessary to establish a seed plot and treat the seed as directed in Jensen's modified hot water treatment, page 10.

Covered Smut of Barley (*Ustilago hordei* (Pers.) Kell. Sw.).

This smut attacks the chaff and the kernels, but the spore mass usually remains covered, each smutted grain (spore ball), being enclosed in a delicate white skin. This smut is often found in the threshed grain in the form of black, irregular masses. It is sometimes difficult to distinguish covered from loose smut of barley, but the former may usually be recognized by its later appearance in the field by the white membrane covering the smut balls and by the coal black color of the spore mass. (See Fig. 7.)

Fig. 6.—Loose or naked smut of barley. (About one-half natural size.)

Fig. 7.—Covered smut of barley. (About natural size.)

Life History.—Some of the spores may be liberated and scattered by the wind before the grain is harvested, but it would seem probable that most of them are dispersed in the threshing and handling of the grain. The disease is carried over as spores adhering to the seed. This smut can get established in the barley plants only when they are in the very young seedling stage. The life history of the fungus causing covered smut of barley is, therefore, for all practical purposes similar to that of the organism causing stinking smut of wheat.

Treatment.—There is much evidence to show that treating the seed with formalin will prevent this smut. (See page 9.)

SUMMARIZED COMPARISON OF LOOSE AND COVERED SMUTS OF BARLEY.

Loose Smut.	*Covered Smut.*
1. Appears earlier; begins to show as soon as the ears appear.	1. Does not show until about two weeks later.
2. Smut masses usually dispersed by the wind soon after they appear, leaving only the bare stalks.	2. Smut masses usually remain until harvest.
3. The smut mass has a dark brown color. The skin around it very soon ruptures.	3. The smut mass is almost coal black, and the white skin usually remains around it.
4. The fungus is carried over as the fungus threads (mycelium) in the seed.	4. The fungus is carried over as the spores on the seed.
5. *Cannot* be prevented by formalin treatment.	5. *Can* be prevented by formalin treatment.

CORN SMUT (*Ustilago zeæ* (Beckm.) Ung.).

This smut is exceedingly common and is familiar to every farmer who grows any corn. The sugar or table corns seem to be more subject to smut than the field corns, but no varieties are known that are entirely free. Many farmers consider the loss due to corn smut too small to demand any particular attention, but the aggregate loss in Ontario is undoubtedly large. In the corn growing sections of Ontario this smut causes an appreciable loss to the growers nearly every year.

Corn Smut is not confined to the ears but attacks also the stalks, leaves and tassels. It produces on the parts attacked peculiar growths, usually spoken of as "boils." These "boils" are sometimes six inches or more in diameter. They are white and polished in the early stage but become darker as they mature and finally rupture and expose a brownish black mass of powder consisting of millions of spores.

LIFE HISTORY.—As soon as the "boils" mature and rupture the spores are scattered by the wind or other agencies. In the soil or in manure the spores germinate and produce great numbers of secondary spores which may infect any of the tender growing tissue of the corn plants. Thus the disease is spread during the growing season. It is carried over the winter as the spores in the soil or in manure. The soil and manure may be contaminated in various ways. The spores may be scattered by the wind or the smut masses may be left on the field or thrown into the refuse or manure pile. Smutted corn may be used for fodder and it is claimed that the spores may pass through the alimentary canals of the cattle without being injured, and may thus get into the manure pile. It is an important fact that the spores of corn smut not only live through the winter in the manure pile, but that they may actually grow and increase in number in the warm fermenting manure. The smut may live for considerable time in the manure heap but will gradually die out.

TREATMENT.—Treating the seed with formalin or bluestone will not prevent corn smut, as it is carried over the winter as the spores in the soil and in manure. Go through the field and remove and burn all smut growths as soon as they appear, as each "boil" when it matures is a source of infection to the healthy plants around it. Avoid fresh manure; it is very likely to contain live smut spores. Practise a rotation of crops; the corn smut spores in the soil will not live for many years and those which are in the soil cannot injure any other farm crop. After

three or four years corn may again be planted with less danger, as many of the spores will have lost their vitality by this time.

METHODS OF PREVENTING GRAIN SMUTS.

There are a number of successful methods of treating grain to prevent smut. The simplest and most efficient methods for the prevention of each kind of smut will be described here.

FIG 8.—Corn smut on ear and tassel. (About one-half natural size.)

DIPPING IN A FORMALIN SOLUTION.

This method will prevent *Stinking Smut of Wheat, Loose Smut of Oats* and *Covered Smut of Barley.*

Materials needed:

Formalin (40 per cent. formaldehyde).
A barrel.
Water.
A coarse sack.
A clean floor or canvas on which to spread out the treated seed.

Mix one-half pint of formalin in 21 gallons of water. Place the seed to be treated in a coarse sack; a bran sack is excellent for the purpose. Fill the sack about three parts full and immerse in the formalin solution for twenty minutes.

During the treatment raise the sack up and down several times in the solution to insure wetting every grain that it contains.

After treating spread the grain out thinly on a clean floor or canvas where it can be stirred and allowed to dry sufficiently to be sown. The sooner it is sown after treatment the better. Twenty gallons of the solution will treat about 20 bushels of grain. Several treatments may be made with the same solution; each lot will require to be immersed for twenty minutes.

Sprinkling With a Formalin Solution.

This method will prevent *Stinking Smut of Wheat, Loose Smut of Oats,* and *Covered Smut of Barley.*

Materials needed:

Same as for dipping in formalin, except that a sack is not required.

In addition: Shovels for mixing the grain.

An ordinary garden sprinkling can.

Mix one pint of formalin with 40 gallons of water. Place the grain to be treated in a heap on a clean canvas or floor. Sprinkle the formalin solution over the grain, then shovel the grain over into another pile so as to mix it thoroughly, then sprinkle and shovel again. Repeat this until every grain is moistened by the solution; then cover the pile with sacking and leave for 3 or 4 hours. At the end of this time spread the grain out thinly to dry; shovelling it over three or four times will hasten the drying. Forty gallons of the formalin solution is sufficient to sprinkle between thirty and forty bushels of grain.

Sprinkling With a Bluestone Solution.

This method is recommended to prevent *Stinking Smut of Wheat* only.

Materials needed:

Same as for sprinkling with formalin, except instead of formalin bluestone or copper sulphate is used.

Dissolve one pound of bluestone by stirring in boiling water in a wooden vessel, then dilute to ten gallons with water. Sprinkle the seed to be treated with this solution as directed for sprinkling with formalin. When completed, spread out to dry at once; do not pile and cover with sacking as directed in sprinkling with formalin.

N.B.—Bluestone has not given as good results here at the College as formalin and should be used only when formalin is not available.

Jensen's Modified Hot Water Treatment.

(Used in connection with a seed plot.)

This method will prevent *Loose Smut of Wheat* and *Naked* or *Loose Smut of Barley.*

Materials required:

Two large kettles or tubs.

Small coarse sacks or wire baskets.

A reliable thermometer.

Supplies of hot and cold water.

*"The clean seed should be soaked for from five to seven hours in water at ordinary room temperature (63 to 72 degrees F.). It should be placed in small

*Bull. 152 Bur. Plant Ind. U.S. Dept. of Agriculture.

loose sacks or wire baskets containing not more than one-half peck each and drained for a short time. It is of the greatest importance that the seed be treated in small lots in order that all of the grain may be quickly and uniformly brought to the desired temperature. Two tubs or vats of water should be provided. In one tub (No. 2) the exact temperature required should be maintained. The other tub (No. 1) is used for bringing the grain to the temperature of the treatment, so as not to lower the temperature in tub No. 2. Galvanized iron tubs of 20 to 40 gallons capacity and kerosene or gasoline double-burner stoves are sufficient for treatment. The drained sacks or baskets of seed should be plunged into tub No. 1 for a minute, then transferred to tub No. 2, and kept agitated while immersed at temperatures and for the periods specified below, the temperature mentioned being maintained as nearly as possible:

"For barley, 15 minutes at 125 degrees F.

"For wheat, 10 minutes at 129 degrees F.

"In treating barley, if the temperature should rise above 126 degrees F. the time of immersion must be reduced to ten minutes at 127 degrees F., or five minutes at 129 degrees F. Above 129 degrees F. there is no safe margin. If the temperature falls slightly below 126 degrees F. time of treatment should be increased in proportion. A temperature lower than 124 degrees F. will not be effective. In treating wheat, if the temperature should rise above 129 degrees F. or fall below 126 degrees F., the time for immersion must be diminished or increased accordingly. Under no circumstances should a temperature of more than 131 degrees F. be allowed. Temperatures below 124 degrees F. are ineffective.

"Seed treated as indicated may be sown as soon as it is sufficiently dry to run freely through the drills. Allowance must then be made for the swollen seed and also for injury in treatment. The increase due to swollen seed can be estimated by measuring seed before and after treatment. The seed may be treated several months before seeding time and then dried quickly and carefully. In many cases the grain germinates as well or better when rested after treatment than if sown immediately. The seed may be dried by spreading it out in thin layers not over 2 inches in depth on a clean granary floor or on canvas and shovelling or raking it from time to time. It must not be allowed to sprout."

This treatment is effective against both smuts but is a rather delicate one to carry out. Should the grain get too hot its germinating power will be injured or destroyed; if the temperature is not high enough the disease will not be reduced at all. It cannot, therefore, be recommended for farm practice for the seed required for the main wheat or barley crop. It is, however, possible to treat a small quantity of seed in this way and with it sow a plot from which to get next year's seed for the main crop. The location for such a plot should be as far as possible from the other wheat or barley fields, and, if possible, in a sheltered situation, so as to avoid the blowing of smut spores in any quantity to the flowers. If the seed grain was successfully treated very few smutted heads should be found in this seed plot, and such as appear should be removed by hand. The grain harvested from this plot should have escaped most of the infection and will yield a comparatively smut-free crop wherever it may be sown and without any further seed treatment.

Precautions to be Taken to Insure Success of Methods Recommended to Prevent Smut.

1. Learn to distinguish the different grain smuts and be sure to use the method recommended for the particular one you wish to prevent.

2. Great care must be taken to see that treated seed is not reinfected with smut spores. Sacks, bins, implements, etc., used in handling smutted grain must also be disinfected. The sacks should be boiled or dipped in a strong solution of formalin (1 pint to 10 gallons) and the seed drill should be cleaned and disinfected with formalin. The floor on which the grain is spread out to dry should first be scrubbed with a strong solution of formalin.

3. If seed wheat to be treated contains bunted grains (smut balls) they must be removed before treating the grain. This can be done with a fanning mill or by placing the grain, about a bushel at a time, in a tub of water and stirring it thoroughly. The "smut balls" being light will rise to the surface and can be skimmed off.

4. Sow the seed as soon after treatment as possible. If the damp grain is placed in bags, in the drill or in any closed place for a few hours there is danger of the vitality of the seed becoming weakened.

5. On no account allow treated grain to sprout or mold or to be frozen when swollen after treatment.

What is Formalin?

Formalin is a clear liquid disinfectant. It is a 40 per cent. solution of formaldehyde gas in water. It can be purchased from almost any druggist, and costs from thirty to fifty cents per pint. It is sold under the names of formalin and formaldehyde. It is important that the purchaser, whatever name he buys it under, secures a guaranteed solution of full strength 40 per cent. formaldehyde. The stock solution should always be kept in a well corked bottle. Formalin, when diluted with water for treating the grain, is not a dangerous poison, although the strong fumes will make the eyes smart and a strong solution will harden the skin temporarily. Formalin is the easiest, safest and most effective disinfectant for the prevention of Stinking Smut of Wheat, Loose Smut of Oats, and Covered Smut of Barley, and it is at the same time comparatively cheap. Formalin *will not* prevent Loose Smut of Wheat or Loose Smut of Barley.

RESULTS OF EXPERIMENTS WITH VARIOUS TREATMENTS TO PREVENT LOOSE SMUT OF OATS AND STINKING SMUT OF WHEAT.

For five years in succession experiments have been conducted by Prof. Zavitz at the Ontario Agricultural College for the prevention of the loose smut of oats and of the stinking smut of wheat. Careful determinations were made each year to ascertain the comparative influence of different treatments. There were in all seven treatments for oats, and five for wheat. In every instance, one sample was left untreated as a basis of comparison. An experiment was conducted in duplicate with oats, and also with wheat each year, there being two varieties of each class of grain used for the experiment. The seed grain was obtained each year from a known source, and where no treatment for smut had been attempted for several years previously. The following treatments were used throughout with the exceptions of numbers 3 and 6, which were omitted from the treatments for the stinking smut in wheat:

(1) *Untreated.* One sample of oats and one sample of winter wheat of each variety were left untreated, in order that the influence of the various treatments might be better observed.

(2) *Immersion in Hot Water.* The grain was placed in a bag and immersed in water at about 115 degrees F. Soon afterwards, it was placed in water which

was kept at a temperature of between 130 degrees and 135 degrees F. The grain was occasionally stirred and allowed to remain in the water for a period of fifteen minutes. It was then spread out on a clean floor to dry, where it was stirred occasionally.

(3) *Immersion in Bluestone Solution for Five Minutes.* A strong solution was made by dissolving one pound of copper sulphate (bluestone) in one gallon of water, and the oats were immersed in the solution for a period of five minutes.

(4) *Immersion in Bluestone Solution for Twelve Hours.* The bluestone solution was made by dissolving one pound of bluestone in twenty-five gallons of water, and the grain was immersed in this solution for a period of twelve hours.

(5) *Sprinkling with Bluestone Solution.* The solution was made by dissolving one pound of bluestone in ten gallons of water, which was used for sprinkling over the grain until it was thoroughly moistened after being carefully stirred.

(6) *Immersion in Potassium Sulphide Solution.* The potassium sulphide treatment consisted of soaking the oats for two hours in a solution made by dissolving eight pounds of potassium sulphide in fifty gallons of water.

(7) *Immersion in Diluted Formalin.* The solution of formalin (40 per cent. formaldehyde) used for the immersion process with oats and with wheat was made by pouring one-half pint of the formalin into twenty-one gallons of water, and the grain was immersed in this solution for a period of twenty minutes, during which time it was stirred occasionally.

(8) *Sprinkling with Diluted Formalin.* One-half pint of formalin was poured into five gallons of water and the grain was sprinkled with this solution and stirred until it was thoroughly moistened.

After the treatments had been made for a few hours and the grain had become sufficiently dried, it was carefully sown on separate plots. When the winter wheat was about ready to cut, it was carefully examined and the heads containing stinking smut were gathered and shelled. The rest of the crop was then threshed and again examined for any smut balls from heads which had been missed in the standing crop. When the oats were coming into head, they were examined frequently and all smutted heads were removed and carefully counted. The accompanying tables give the average results in percentage of grains of winter wheat affected with stinking smut and of heads of oats affected with loose smut in each of the five years during which each experiment was conducted. Besides this information, the average yield of oats per acre for the five years and the average yield of winter wheat per acre for three years are included.

RESULTS OF EXPERIMENTS TO KILL THE LOOSE SMUT OF OATS.

Materials.	Percentage of Smut.						Average yield of Grain per acre. 5 years.
	1st year test.	2nd year test.	3rd year test.	4th year test.	5th year test.	Average 5 years.	
							Bushels.
1. Untreated	5.5	3.9	11.6	4.3	3.4	5.7	60.3
2. Hot Water	.9	.0	.0	.1	.0	.0	63.7
3. Bluestone, 5 minutes	1.7	.9	.7	.6	.1	.8	58.5
4. Bluestone, 12 hours	.6	.0	.0	.1	.0	.1	56.0
5. Bluestone, sprinkled	.9	2.0	1.4	.6	1.6	1.3	61.8
6. Potassium Sulphide	3.4	.1		1.5	.7	1.2	66.2
7. Formalin, immersed	.0	.0	.0	.0	.0	.0	68.3
8. Formalin, sprinkled	.0	.1	.0	.0	.0	.0	61.3

RESULTS OF EXPERIMENTS TO KILL THE STINKING SMUT OF WHEAT.

Materials.	Percentage of Smut.						Average yield of Grain per acre 3 years.
	1st year test.	2nd year test.	3rd year test.	4th year test.	5th year test.	Average 5 years.	
							Bushels.
1. Untreated	3.6	9.3	.6	.6	6.8	4.2	38.0
2. Hot water	.0	.0	.0	.0	.0	.0	40.6
4. Bluestone, 12 hours	.0	.0	.0	.0	.0	.0	40.2
5. Bluestone, sprinkled	.0	.2	.0	.0	.1	.1	41.1
7. Formalin, immersed	.0	.0	.0	.0	.0	.0	43.3
8. Formalin, sprinkled	.0	.0	.0	.0	.0	.0	36.3

The results show that the greatest yields of both winter wheat and oats per acre were produced from the grain which was immersed for twenty minutes in a solution made by adding one-half pint of formalin to twenty-one gallons of water. They also show that this treatment was effectual in completely killing the smut. Of the different bluestone treatments for smut in oats the most effectual was No. 4, but even that was not as satisfactory as the treatment in which the oats were placed in the formalin solution. It will be observed that No. 3 and No. 4 treatments with oats apparently injured the germination of the seed slightly, and consequently lowered the yield of grain per acre. It will also be noticed that the sprinkling with the formalin solution reduced the yield of winter wheat, the average being nearly two bushels per acre less from the treated than from the untreated seed.

STEM RUST OF GRAIN (*Puccinia graminis*, Pers.).

This is our most conspicuous grain rust. It occurs on wheat, oats, rye, barley, and many wild grasses. It first appears early in the summer as dark, reddish-brown, or rust-colored lines, chiefly on the stems and sometimes also on the leaves and chaff. This stage of the disease is known as the Summer or Red Rust. On looking closely at the red lines on the stems they appear powdery, and are seen to be surrounded by the ragged edge of the ruptured skin (epidermis). This red powder comes off readily, and in badly rusted grain the hands and clothing of one walking through the field become thickly coated with the red dust. Later in the season, as the grain ripens, the stems become covered with black lines. This stage of the disease is known as the **Black Rust.**

When the plants are badly rusted the grains do not properly mature and are light and shrivelled; hence the grain is inferior in quality and of a low grade. The yield is sometimes reduced very much (40 to 50 per cent.). In years when the rust is bad, the loss undoubtedly amounts to many thousands of dollars in Ontario. Not only does the rust organism attack grain and grasses, but it also attacks a shrub known as the barberry, producing on the underside of the barberry leaves yellow pustules, which, when examined with a hand lens, are seen to be composed of clusters of little cup-like structures (æcidia). The barberry is not injured, however, to any great extent by the rust organism.

LIFE HISTORY OF THE STEM RUST.

The Stem Rust of Grains, like many other rusts, has a complicated life history. There are three distinct stages through which it passes during the year. It

the summer when the grain is growing the red rust stage appears on the stems as lines of rust-colored powdery material. This powder consists of numerous oval, orange colored, thin walled spores, known as summer or red rust spores (uredospores). These spores spread the disease during the growing season. When the grain begins to ripen the fungus threads (mycelium) inside the stems, instead of producing summer spores, begin to produce dark-colored, thick-walled, two-celled spores, known as black rust spores or winter spores (teleutospores). See Fig. 9. When the winter spores are produced, the rust spots change from red to black. These winter spores do not germinate until the following spring, and then they are not able to start the disease on the grain again directly, but they are able to

FIG. 9.—Black rust spores (Teleutospores) of stem rust of grain. (Magnified many times.)

FIG 11.—Drawing of longitudinal section through a cluster cup (Æcidium) of stem rust of wheat, showing the chains of cluster-cup spores (Æcidiospores). (Magnified many times.)

FIG 10.—Cluster cups (Æcidia) of stem rust of grain on lower surface of barberry leaf. (Magnified about three times.)

produce another form of the rust on the leaves of the barberry. The barberry rust looks very different from the rust on the grain. Thick yellow spots are formed on the barberry leaves, the undersides of which bear numbers of little cups called cluster cups (æcidia). See Fig. 10. In these cups are borne numerous chains of thin-walled, oronge-colored spores, termed cluster-cup spores (æcidiospores). See Fig. 11. These cannot cause the rust again on the barberry, but if they are blown to growing grains or grasses they can infect them and give rise again to the red rust or summer spore stage of the Stem Rust.

Thus it will be seen that for the Stem Rust to complete its whole life history there must be present the grains or grasses for the production of the summer

spores (uredospores), and the winter spores (teleutospores), and also the barberry for the production of the cluster-cup spores (æcidiospores).

The Stem Rust (*Puccinia graminis*) attacks wheat, oats, rye, barley and many wild grasses, such as wild barley, quack grass, etc. There appears, however, to be a slight difference in the varieties of rust occurring on the different kinds of grain. The stem rust of wheat will not readily infect oats or rye, and will not infect barley as readily as other wheat plants, each of these grains apparently having a race of stem rust more or less peculiar to itself.

The Barberry is not Essential for the Continuance of the Stem Rust.

When it was first known that the stem rust fungus spent part of its life history on the barberry it was thought that by doing away with the barberry the stem rust could be prevented. However, in the West and in Australia, where the barberry is practically absent, the stem rust is present and causes enormous losses in rust years.

How Does the Stem Rust Winter Over Without the Barberry?

Since the stem rust exists in places where the barberry is practically unknown, how does it continue to live from year to year? Careful investigations and observations have shown that there may be four ways in which the stem rust may get through the year without the barberry:

1. It has been shown that the summer spores (uredospores) which are formed on the grains and grasses during the growing season may remain alive over the winter on straw, stubble, or dead grasses covered by the snow, and that these may germinate and start the red rust again in the spring.

2. When winter wheat is grown it may become rusted in the fall and, as the wheat remains alive all winter, the fungus threads in the tissues may also remain alive. As soon as the wheat starts growing again in the spring new crops of summer spores may be produced, and the red rust started again in the spring. There are also many wild grasses on which the stem rust lives. It may winter over on these in the same way that it does on winter wheat.

3. In the southern part of the United States the winter grains (wheat, oats and rye) remain in a growing condition nearly all winter, and it is possible for the rust to produce new crops of summer spores continuously. These spores are very light and may be carried by the wind for very long distances, hundreds of miles in fact; hence these summer spores may be brought north in the spring in quantities sufficient to start the rust on the grains as soon as they come up in the spring.

4. A study of rusted wheat plants has shown that the rust threads (mycelium) may even enter the grain, and that spore beds may be produced under the bran layer around the germ. It has been shown that these rust threads are capable of growing when the seed germinates. It may be possible that they can infect the wheat seedlings; this point has not yet been proved.

The Barberry Does Increase the Severity of Stem Rust.

While the rust fungus may live over from year to year without the barberry, it is now generally conceded by all who have made a study of the matter that the amount and severity of the stem rust is very much increased by the pre-

FIG. 12.—Drawing of twig of barberry, showing leaves and berries.

sence of the barberry in the neighborhood of the grain fields. This is what might be expected from a consideration of the fact that by passing a portion of its life on the barberry the rust fungus is invigorated, and its power of producing rust on grain or grasses again multiplied many times over.

The Barberry.

There are several species of barberry grown in Ontario, but not all of them harbour grain rust. The barberry which is most frequently found in Ontario is the Common Barberry (*Berberis vulgaris*). This species and the purple-leaved variety of it do harbour the stem rust.

The Common Barberry (*Berberis vulgaris*, L.) is a native of Europe. It has been much planted in Ontario for ornamental purposes and has become wild in some localities. It is a spiny shrub from six to nine feet high, with yellow wood, arching branches and grey twigs. The leaves are bright green, smooth, somewhat oval, from one to three inches long, the margins with bristly teeth. The flowers are small, yellow, and borne in long drooping clusters (racemes). The berries are oblong, red and sour. (See Fig. 12.) The purple-leaved variety (*Berberis vulgaris*, var. *atropupurea*, Rgl.) is similar, except that the leaves are dark purple in color. It is now contrary to law to plant the common barberry (*Berberis vulgaris*, L.) in Ontario. (See Act respecting barberry appended.) If barberries are required for ornamental purposes the Japanese Barberry (*Berberis thumbergie*, D.C.) may be planted, as this species does not harbour the rust.

Leaf Rust of Wheat (*Puccinia rubigovera tritici*, Carleton).

In addition to the stem rust, wheat is attacked by another rust, the leaf rust. This rust is confined principally to the leaves of the wheat plant. It usually appears early in the season and is sometimes quite abundant a month before the stem rust is noticed to any extent. The leaves of the wheat plant become covered with numerous small, oval spots of light red color and powdery appearance. Each spot or pustule (sorus) is surrounded and partly covered by the broken skin (epidermis) of the leaf. As the wheat matures the red spots are replaced by brownish-black patches which remain covered by the skin (epidermis). Although the leaf rust is widely distributed, occurring everywhere where wheat is grown, it does not cause as much damage as the stem rust.

Life History.—The life history of this rust is very similar to that of the stem rust, except that no cluster-cup stage has been found, and consequently this rust is not harbored by the barberry or any other plants, so far as is known, in the same manner as the stem rust.

Summarized Comparison of Stem Rust and Leaf Rust of Wheat.

Stem Rust.	*Leaf Rust.*
1. Rust spots are mainly on the stems.	1. The rust spots are mainly on the leaves.
2. The spots of the summer rust are dark red in long lines on the stems.	2. The spots of the summer rust are light red or orange colored, in small oval pustules on the leaves.
3. In the winter rust stage (black rust) the spots are nearly black, in long lines on the stems; skin ruptured.	3. In the winter rust stage (black rust) the spots are brownish-black in small scattered patches on the leaves; skin not ruptured.
4. Cluster-cup stage on the Barberry.	4. Cluster-cup stage not known.

Leaf Rust or Crown Rust of Oats (*Puccinia coronata*, Cda.).

Oats are also attacked by leaf rust. As the name implies, this rust is mainly confined to the leaves, though it may occur to some extent on the leaf bases and stems of the oat plant. Early in the season the leaves and sometimes the leaf bases become thickly covered with small oval or elongated, light red or orange-colored spots. Each spot or pustule is surrounded by the broken skin (epidermis). See Fig. 13. Each of these spots is composed of orange-colored powdery material consisting of numerous spores. Sometimes this red rust on the leaves is so abundant that the whole field will have a decidedly reddish tinge. As the plants mature, the reddish spots on the leaves and leaf bases are replaced by the small, greyish black spots of the black or winter rust. These black spots or pustules remain

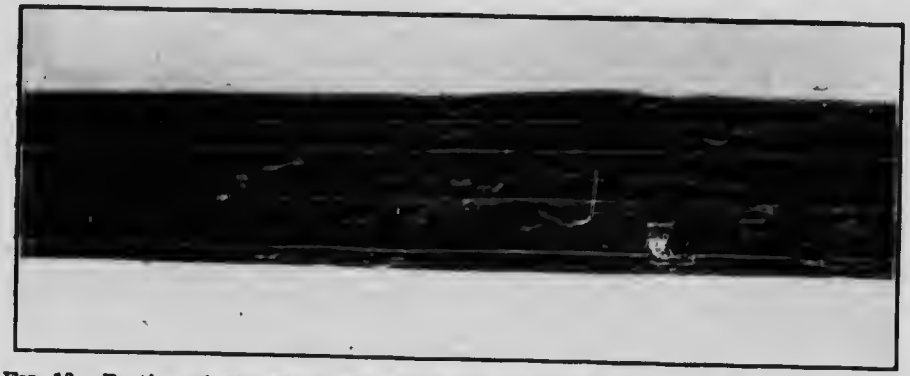

Fig. 13.—Portion of oat leaf, showing the red or summer rust spots of leaf or crown rust of oats. (Magnified between three and four times.)

Fig. 14.—Drawing of the black rust spores (Teleutospores) of leaf rust or crown rust of oats. (Magnified many times.)

covered by the skin (epidermis), and are frequently arranged in circles around the old spots of the red rust. As a rule the [illegible]sts do not do a great deal of damage, but in this respect the leaf rust of [illegible] exception, as its attacks sometimes damage the oat crop very considerably

Life History.—The life history of this rust is similar to that of the stem rust, except that the cluster cup stage is passed on a shrub known as the Buckthorn instead of on the Barberry. This rust is thus harboured by the buckthorn and not by the barberry.

Summarized Comparison of Stem Rust and Leaf Rust or Crown Rust of Oats.

Stem Rust.	*Leaf Rust or Crown Rust.*
1. Rust spots are mainly on the stems.	1. Rust spots mainly on the leaves; sometimes on the leaf bases.
2. The spots of the summer rust are dark red in long lines on the stems.	2. The spots of the summer rust are light red or orange in color, oval or elongate in shape.
3. In the winter rust stage (black rust) the spots are nearly black in long lines on the stems; skin ruptured.	3. Spots of the winter rust (Black rust) greyish-black, very small, often arranged in circle, and the skin not ruptured.
4. Cluster-cup stage on the Barberry.	4. Cluster-cup stage on the Buckthorn.

The Buckthorn (*Rhamnus cathartica*, L.).

This is the shrub on which the crown rust of oats (*Puccinia coronata*) is harboured. It is a native of Europe, but is quite frequently used for hedges and ornamental purposes in Ontario, and has to some extent escaped from cultivation. It is a shrub or small tree, from six to eighteen feet high, with glossy, ovate, green leaves and thorny branches. The flowers are small and inconspicuous being greenish in color. The berries are spherical, black in color, and very bitter in taste.

The writers believe that it would pay farmers to destroy the buckthorns growing in or near their fields, and thus do away with the means by which the fungus which causes the leaf rust or crown rust of oats multiplies itself so abundantly.

Why the Amount of Rust Varies.

Since the rust has so many ways of living over the winter it may well be asked "Why do we not have our grain crops destroyed every year by rust, and why even in 'rust years' are some fields rusted worse than those around them." This is answered by the fact that not enough of the rust fungus lives through the winter to infect all the grain plants in the spring, so that it must be spread during the growing season. The extent to which rust will spread depends very largely on soil and atmospheric conditions. If there are periods of muggy weather, especially during the time when the grain is heading out, the rust will spread much more rapidly than if the weather is dry and clear. Cool weather also gives the rust a chance to spread, as it lengthens the growing period of the grain. In wet seasons the grain growing in low poorly drained portions of the fields is usually more severely rusted than on the higher better drained parts, for the reason that the soil in the undrained places remains cold longer in the spring, causing the plants to develop more slowly, and hence they are longer exposed to infection. In these places also the excessive moisture keeps the grain damp, and the rust spores have a better chance to germinate and infect the growing grain. The grain growing along hedges, near woods, and in places sheltered from the wind by hills, is also often more badly rusted because the air does not have free circulation and the plants remain damp after dew or rain for a much longer time than in places where the wind has an opportunity to dry them quickly.

FIG. 15.—Drawing of twig of buckthorn, showing leaves and berries. (About natural size.)

Suggestions as to How to Prevent Loss from Rust.

There is no way of treating the seed or spraying the crop so as to prevent rust. It is impossible to control rust entirely, but loss from rust may be reduced considerably by acting upon the following suggestions:—

1. Destroy as far as possible the Common Barberry (*Berberis vulgaris*) and the Buckthorn (*Rhamnus cathartica*) growing in Ontario. Rust may cause serious loss in districts where these shrubs are not found, but, when they are present, they do undoubtedly tend to increase the amount.

2. See that fields on which grain is to be grown are well drained. Rust is nearly always worse on poorly drained land. Such land remains colder longer in the spring, and hence the germination and early growth of the grain are retarded. In wet seasons also grain ripens more slowly on poorly drained land. This slow development of the crop and the excessive moisture provide the conditions most favorable for the development of rust.

3. Endeavor to have the crop mature as early as possible. This can be done to some extent by early seeding in a well prepared seed bed.

4. Avoid those varieties of grain which give poor returns and are also badly injured by rust. See table provided by Prof. Zavitz showing the extent to which different varieties are attacked by rust.

5. Do not mix varieties of seed grain, such as early and late ripening varieties of oats, but use only pure seed of one variety to secure uniform ripening.

6. Treat all seed grain to prevent smut, as plants infected with smut are very subject to rust, which may get started on them and then spread to healthy plants.

7. Sow only sound, plump grain. This can be secured by the careful use of the fanning mill. Shrivelled grain is very likely to have been produced by badly rusted plants.

8. On rich soils be careful in the use of manures containing large amounts of nitrogen, such as barnyard manure and nitrates. Such manures on rich soil produce an excessively rank growth, which invites rust.

9. Rotation of crops, proper manuring, thorough cultivation, freeing the fields from weeds, and all such farm practices which tend to promote healthy growth and the proper maturing of the grain lessen the chances of rust causing serious loss.

TABLE SHOWING THE EXTENT TO WHICH DIFFERENT VARIETIES OF GRAIN ARE ATTACKED BY RUST.

Experiments have been conducted by Prof. Zavitz at the Ontario Agricultural College in carefully testing different varieties of farm crops. The following table gives the average of five years' results (1910-1914 inclusive) in number of days in reaching maturity, in yield of grain per acre, and in per cent. of rust on the straw of each of eight varieties of oats, three varieties of six-rowed barley, and ten varieties of winter wheat:—

Varieties.	No. of Days from Seeding until Maturity.	Bushels of Grain per Acre per Annum.	Per cent. of Rust on Straw.
Oats:—			
Early Ripe	100	66.6	6
Danbeney	102	66.0	6
Siberian	109	84.5	7
Banner	111	67.1	9
Tartar King	108	70.3	12
Abundance	109	82.0	14
Storm King	108	64.7	16
Black Tartarian	115	54.6	21
Barley:—			
Mandscheuri	100	61.9	2
Mensury	97	47.4	4
Zulu King	98	54.9	6
	Average date of Maturity.		
Winter Wheat:—			
Kharkov	July 26	47.3	4
Tuscan Island	July 25	41.1	5
Banatka	July 27	42.0	6
Turkey Red	July 26	38.3	7
Imperial Amber	July 24	45.4	8
North Wester	July 25	39.5	9
Treadwell	July 26	33.5	11
Grand Prize	July 26	47.6	12
American Wonder	July 24	40.1	14
Abundance	July 25	39.7	17

AN ACT RESPECTING THE BARBERRY SHRUB.

HIS MAJESTY, by and with the advice and consent of the Legislative Assembly of the Province of Ontario, enacts as follows:

1. This Act may be cited as *The Barberry Shrub Act.*

2. In this Act "Barberry" shall mean the species *Berberis vulgaris L.*

3. Every person who plants, cultivates or sells the shrub known as the barberry shrub shall incur a penalty not exceeding $10, to be recoverable under *The Ontario Summary Convictions Act.*

4. The council of any municipality may order the owner or occupant of any land on which any hedge or fence formed by such shrub or any plant of such shrub is growing to remove and destroy the same, and upon his neglect or refusal so to do within one month after the service of notice in writing requiring such removal and destruction, the council may cause the same to be removed and destroyed, and in such case he shall not be entitled to compensation for such removal and destruction.

5.—(1) If within thirty days after receiving the notice, the owner or occupant removes and destroys such shrub, he shall be entitled to compensation for the value of the plant and the cost of removal.

(2) In default of agreement, the amount of such compensation shall be determined in writing by the fence viewers of the municipality, and the amount agreed upon or awarded shall be paid to the owner or occupant by the treasurer of the municipality.

6.—(1) Where any person has planted or has growing upon land owned or occupied by him and situate within any city, town, or incorporated village any hedge or fence formed by such shrub or any plants of such shrub, the Minister of Agriculture may, upon petition signed by at least three owners or occupants of lands in an adjoining township, and after the report of one or more qualified persons appointed by the Minister for such purpose, require the owner or occupant to remove and destroy such hedges, fences or plant, and upon his neglect or refusal to do so within one month after the service of notice in writing requiring such removal and destruction, the Minister may cause the same to be removed and destroyed.

(2) Where such owner or occupant removes and destroys such hedge, fence or plant as required by the Minister, and such hedge, fence or plant was planted before the 30th day of April, 1900, he shall be entitled to such compensation as the Minister sees fit to allow, to be paid out of the Consolidated Revenue Fund.