Can We Increase the Yield of Cereals By Reducing Rootrot Injury?[1]

RODERICK SPRAGUE[2]

IT IS THE PURPOSE of this note to discuss the chances of reducing rootrot injury by developing new varieties of cereals, or by the wider use of known resistant varieties, and also to bring up-to-date the local information obtained during the past four years. Most of the discussion will deal with wheat.

Causes of Rootrot in North Dakota

Soil-borne or seed-borne fungi, which destroy or injure the underground parts of cereals in North Dakota, may attack the plant during its (1) seedling stage (seedling blight), (2) during the active growing season in May and June (root browning and HELMINTHOSPORIUM rootrot), and (3) towards and during the ripening period in July and early August (common rootrots).

The most important parasite, taken as a whole, is the one causing the HELMINTHOSPORIUM or "common" rootrot (H. SATIVUM Pamn., King, and Bakke). This fungus not only rots the roots and the stem bases, but also causes blotches on the leaves and glumes, and occurs on moldy seeds. It is one of the components of "durum blight", and, when moldy seed is planted, usually causes seedling blight.

Seedling blight has been widely discussed as being due to several causes, but in North Dakota most of the seedling death of wheat and barley is due to seed-borne HELMINTHOSPORIUM. Root browning (caused by PYTHIUM ARRHENOMANES Drechs.) does not develop to any extent until a number of weeks after the wheat has emerged and is therefore, not a serious factor in seedling blight. Root browning is nevertheless important in late May or June as a cause of the death of many small roots on cereal plants. It reduces yield and permits common rootrot fungi to follow later in the summer, resulting in "white heads" and dead plants. This

[1]Cooperative investigations between the Divisions of Cereal Crops and Diseases, Forage Crops and Diseases, Dry Land Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, and the Nursery Division, Soil Conservation Service, U. S. Dept. of Agriculture; and the North Dakota Agr. Exp. Station.

[2]Pathologist, Division of Cereal Crops and Diseases.

root browning fungus is also the main cause of a widespread seedling death of grasses (crested wheatgrass, brome, Russian wild-rye, green needle grass, etc.). But, as mentioned, it does not directly kill an appreciable number of cereal plants in our area.

In the States to the east of North Dakota seedling blight is sometimes caused by the head scab fungus (FUSARIUM GRAMNEARIUM Schw.). Fortunately, in North Dakota scab is usually limited to a narrow strip in the Red River Valley adjacent to Minnesota. It can usually be found in the region south of Fargo and in 1943 was also common at Fargo and north of there. While reported as far west as Valley City and believed by some to occur throughout the State most of the collections seen, which were made from fields west of the extreme eastern edge of the State, were not infected with true scab, but with pink molds. These molds were due to non-parasitic or weakly parasitic species of FUSARIUM (frequently F. SPOROTRICHOIDES Sherb.). Gordon and Sprague[3] found that FUSARIUM spp. isolated from the roots of cereals and grasses in North Dakota and adjacent States in 1940 were, for the main part, harmless fungi or were weak parasites. The two most important FUSARIUM parasites of cereals (F. GRAMINEARUM and F. CULMORUM) (w. g. Sm.) Sacc. were practically absent from the region. This study has been continued to date, and the results verify our 1940 findings as follows:

Fungi	Number of pure culture isolations obtained in: 1940	1941	1942	1943 (to Aug. 15)	Total
Scab-causing Fusarium spp.	3	7	19	19	48
Weakly parasitic or non-parasitic species of Fusarium[4]	1712	1326	3,008	1292	7,738

Three samples of mature and nearly mature wheat and barley collected at Fargo, August 7, 1943 yielded the following number of pure cultures of fungi from diseased roots: scab *Fusarium* 19, weakly parasitic *Fusarium* spp. 6, *Helminthosporium sativum* 6, non-parasitic miscellaneous molds 3, root-browning *Pythium* 3. No doubt an intensive study of seedling blighted

[3]Gordon, W. L. and R. Sprague. Species of Fusarium associated with rootrots of the Gramineae in the Northern Great Plains. Pl. Dis. Reptr. 25: 168-186. 1941.

[4]Mostly *F. equiseti* (Cda.) Sacc., *F. oxysporum* (Schl.) em. Snyd. et Hans., *F. scirpi* var. *acuminatum* (Ell. and Ev.) Wr., and *F. Sporotrichioides* Sherb.

plants of wheat and barley in the counties adjacent to Minnesota would disclose a considerable amount of scab-causing *Fusarium* fungi associated with these blighted plants. But out of 2451 collections of cereals and grasses made during the last 4 years, scab-forming fungi have been significantly absent from the roots of these plants throughout the rest of the wheat growing regions in the State. The presence of scab in the eastern part of the State, however, must be considered as a potential menace and seed wheat obtained from this area should be Ceresan-treated to kill the seed-borne spores.

It appears from our isolations and from a long series of inoculation tests in the greenhouse, that most of the seedling blight in North Dakota is due to seed-borne and less often soil-borne *Helminthosporium*. Since Brentzel has shown that appreciable control can be effected by treating seed with New Improved Ceresan[5], seedling blight need not be serious, particularly if good plump seed is used.

Many poor stands of grain attributed to seedling blight are due, instead, to wire worm, particularly in weedy fields. When large areas of seedlings are wiped out in grain fields, it is likely that wire worms and not fungi are the cause. The worm destroys a short length of stem at the ground line, leaving a shredded brown leaf sheath connecting the above ground parts with the roots. The plant soon dies, is whipped away by the wind, and the denuded area replaced by weeds. Since the weeds favor continued increase in wire worms, and some weeds, such as pigeon grass, also serve as carriers for detrimental soil fungi (*Pythium, Rhizoctonia, Fusarium, Helminthosporium*), both wire worms and rootrot tend to increase in affected areas. This condition is particularly serious in certain sandy soils in Grand Forks County and adjacent territory. Elimination of weeds will not only greatly reduce injury to wheat by starving out wire worms, but will reduce loss from rootrot as well. Munro and Telford discussed control of wire worm in 1942[6].

Of course where weak, moldy, poorly cured seed is sown, even though it may germinate up to 80 percent or so in sterilized soil, it is liable to rot in the ground when field-sown if cold wet weather occurs. Damping-off *Pythium*, weak *Fusarium* rots, and various black molds destroy the starch of these moldy seeds as they lie in the ground, and sometimes only a few weak seedlings emerge. We noted this condition in several instances during the wet, retarded spring of 1943. The use of plump, Ceresan-treated seed would have avoided loss to a large extent.

The loss in yield due to seedling blight, rootrots, and footrots is difficult to calculate. Most of our estimates are no doubt too conservative. If we take "normal" field soil and sterilize it by heating to about 75° C. we find when comparing the yield

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[5]Brentzel, W. E. Blight and other damage of durum wheat in 1940. II Effect of blights and other damage on durum and hard red wheat seed. N. Dak. Sta. Bul. 296, pp. 9-14. 1941.

[6]Munro, J. A. and H. S. Telford. Recent progress in wireworm control. Bimonthly Bul. 5: (2) 7-11. 1942.

of cereals grown on this soil to that of cereals grown in unsterilized soil from the same place, that the grain in the sterilized soil is darker green, taller, more vigorous and may sometimes produce as much as 50 percent more seed. Usually the increase will range from about 10 to 25 percent.

In the fall of 1939 Brentzel treated a small area with a volatile liquid, chloropicrin, at McCanna, North Dakota. This material completely sterilizes the soil, destroying all fungi, but is far too expensive to be practical for use in grain fields. In the spring of 1940 we drilled across this treated strip. The increase in vigor, height of plants, and size of heads was remarkable in the treated part where all yield-depressing fungi were killed out. Of course in this small area the parasitic fungi gradually worked back into the clean chloropicrin-treated area so that by harvest time rootrot was again present in the treated part also. However, this single trial gave strong indication of what we might expect in even "normally" healthy fields if we could commercially eliminate parasitic and detrimental molds from the roots of cereals.

Since in the field we rarely have plots which are chemically sterilized, to compare with, we are forced to estimate the losses based on the symptoms present and on the seriousness of the lesions or injuries which occur on the individual plants. We have, therefore, taken samples of plants at random in the fields or plots and segregated them into seven groups or classes depending on the amount of disease present in each particular plant. These seven classes or groups range from one that is composed of the healthy plants to the seventh group, which includes the dead ones. Between these two extremes are five other classes graduated as to seriousness of injuries. The relative potential loss in yield in these seven classes is as follows: healthy—no appreciable injury; slight injury—5 percent reduction in yield, that is, the plants in this group will yield about 95 percent as much as the healthy ones; moderate injury—ten percent loss in yield, the most common group; moderately severe—20 percent loss; severe—30 percent loss; very severe—60 percent loss; dead—100 percent loss if killed before the heads are filled. After the plants have been grouped in these seven classes loss is calculated by multiplying the percentage loss of each group and dividing by the total number of plants for all seven classes. This gives us in percent the approximate loss in yield due to rootrots that are evident at the time the counts were made. We have employed this technique for the past 14 years and have found it usable in determining comparable losses in varieties and in rotation plots. Of course the amount of injury found will depend on when we take our records. When examinations are made in June, root browning and *Helminthosporium* are active, and a majority of the fields will show from 4 to 8 percent loss in yield. A month later the root browning symptoms are largely gone. The loss in the same field, however, is usually appreciably higher than it had been in June. The symptoms at this latter date are those of common rootrot induced by *Helminthosporium,* and an accompanying group of minor, weaker fungi, which in the aggregate are of economic importance. Injury at this time and at harvest will vary from as low as 5 percent in some fields, to as high as 35 percent, and in barley will run much higher at times. It is probable that the obscured root browning symptoms are not fully appreciated at this later count, and that the loss in yield due to all fungi during the whole period wheat, is somewhat over 10 percent for the State as a whole. Referring back to the increase in yield obtained by sterilizing the soil it becomes evident that such may be the case.

Varietal Resistance

A leading question, therefore, is—Can we reduce this 10 percent or so loss by use of resistant wheat varieties? The answer at present is, yes, to a moderate extent. Four years observation of the degree of infection of variety trials of wheat with root rot indicate that all varieties are susceptible but that there is some variation in the degree of susceptibility. The varieties which are agronomically better adapted to a certain area usually have less rootrot than the varieties less well adapted to the particular region. Some are variable, their rootrot tolerance varying from region to region, and to some extent from season to season. Thus Marquis is considered somewhat resistant to root browning (*Pythium arrhenomanes*) in Saskatchewan[7], is not outstandingly susceptible at Dickinson, is more susceptible at Mandan, and highly susceptible at McCanna, North Dakota.

For the purpose of this report the wheats can be divided into three unequal groups as follows:

Very Susceptible: Ceres, Kubanka, Marquis (eastern N. Dak.), Pentad.

Susceptible: Carleton, Mindum, Newthatch, Pilot, Regent, Rival, Thatcher, Vesta.

Moderately Susceptible: The emmers (*Triticum diccoccum* and *T. timopheevi*).

The great majority of the common wheats grown in North Dakota are comparatively similar in their reaction to the rootrot complex, and all are at least susceptible to the fungi involved. There is a definite tendency for varieties with sturdy straw such as Rival to be somewhat less diseased in most parts of the State than some others, while Pilot appears to be somewhat less injured by the May-June root browning attack than many of the other common wheats. The durums as a class are very susceptible to *Helminthosporium,* but an exception is Mindum, which is no more susceptible than a number of common wheats. Carleton may owe its superiority in rootrot tolerance over Kubanka to its Mindum parentage, although Vernal emmer also was employed in breeding this new wheat. There is some chance that improvement in rootrot tolerance may be obtained by use of a recently introduced Eurasian

[7]Vanterpool, T. C. Root-rot diseases of cereals. Univ. of Sask. Agr. Ext. Bull. 101. 1-4. 1940.

species of wheat (*T. timopheevi*), which shows definitely more resistance to rootrot than the common wheats. However, because of other less desirable qualities, development of commercially desirable wheats from a cross with this species would likely entail long tedious work. There also may be foreign varieties of wheat which may show some rootrot resistance, but all evidence so far is not encouraging that any highly superior rootrot resistant wheat will be developed very soon.

There are several hybrids in the cereal nurseries in the region, which give promise of being slightly more resistant than any approved wheat varieties now grown.

Crop Rotation

Besides varietal resistance, our best chance of reducing rootrot losses has been said to be that of crop rotation. Except for avoidance of flagrantly careless, continuous one cereal crop practices, rotation is not as effective as might be expected. Four years of study of rotation plots at the stations at Mandan and Dickinson indicate that seasonal and soil differences show greater variations than the practices employed. In general, considering rootrot alone, the use of oats or corn before wheat in rotations is desirable. Oats eliminates some of the *Helminthosporium*, it carries little parasitic *Fusarium* in most of North Dakota, and while somewhat susceptible to "damping-off fungi" (*Pythium debaryanum, Hesse P. irregulare Buisman*) these do not seriously injure wheat. Green manures or barn yard manure are a gamble. If the season is moist rootrot is sometimes not increased, and the yield very definitely is, but in dry years green manure favors rootrot. In dry years fall plowing seems to increase rootrot. In 1940 this was particularly notable. In wet years the results are inconclusive. Tillage methods that tend to accumulate the refuse on the surface (trashy fallow) or that favor grass weeds tend to increase rootrot. Burning refuse produces erratic results in control of the disease. Use of grass in rotations also gives somewhat uncertain results, but after the second year from plowing under, and for a short period of years thereafter, rootrot tends to be less prevalent in wheat on such ground. At present we believe that good agronomic and conservation practices will be as useful as any in keeping rootrot losses at a practical minimum. Although it is usually not recognized as such, the injury due to rootrot fungi has long been considered in the management of farms.

Use of Fertilizers and Chemicals

Trials at Mandan and at Langdon give little indication that rootrot can be controlled by use of commercial fertilizers. When phosphates are drilled in with the seed injury is often increased. Numerous chemicals have been tried and are being tried in our trials, but so far none have proven of any value in commercially controlling soil-borne rootrot. Seed treatment is effective insofar as it eliminates parasitic fungi and seed-rotting fungi on the seed, but its value is fleeting in protecting the sprouting seed from the parasitic forms in the soil.