INTERACTIONS AMONG BIOTIC VARIABLES AFFECTING COCHLIOBOLUS SATIVUS AS A PATHOGEN OF CEREALS'

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Abstract

Present knowledge of seedling blight and common root rot diseases of cereals caused by Cochliobolus sativus is reviewed with particular reference to etiology and control. Interactions known to occur between C. sativus and other fungi are described and possible interactions between the pathogen and faunal and viral variables discussed. It is suggested that all variables that may affect disease incidence first be examined and then narrowed down to specific modifying factors. The use of selective chemicals may assist in determining how biotic variables modify common root rot.

Introduction

Cochliobolus sativus (Ito & Kurib.) Drechsl. ex Dastur [conidial state, Helminthosporium sativum Pamm. King & Bakke, syn. Bipolaris sorokiniana (Sacc. in Sorok) Shoem.] is the main causal organism of four important diseases of cereals: black point (kernel smudge), seedling blight, leaf blotch, and common root rot. It is the least specialized of the virulent and prevalent Helminthosporium species present on graminaceous hosts (11). Fusarium culmorum (W. G. Sm.) Sacc. and other Fusarium spp. (20) are often associated with C. sativus in common root rot. Black point cannot be controlled: seedling blight-can be partially controlled with seed treatment fungicides: but attempts to control common root rot, studied for 40 years in Canada, have been less successful. Studies on common root rot are extremely difficult because of the existence in soil of numerous complex interrelationships among biotic and abiotic variables. This report summarizes present knowledge of the diseases, with emphasis on biotic and abiotic interactions, and proposes possible areas for future research.

THE MICROFLORA OF SEEDS AS RELATED TO THE &ED-BORNE PATHOGEN

C. sativus, with Alternaria sp. and other "field fungi", is a common component of the air-spora which invade developing heads of cereal plants (22, 25). The invasion is mainly dependent on the weather during the time the kernels are developing and maturing (13). In the swath, other fungi, including Trichothecium sp. and Streptomyces spp. ("harvest fungi") (31) and Penicillium spp. ("storage fungi") (8) also may infest the seeds. The bacteria, yeasts, fungi, nematodes, and viruses known to occur in barley have been listed by Pepper & Kiesling (33). Many fungi could directly or indirectly affect C. sativus on the grain (Fig. 1). Interrelations occurring among C. sativus and other fungi, insects, mites, and environmental variables in stored grain have been investigated by Sinha et al. (39).

Machacek et al. (24) found that seed samples heavily infested with C. sativus originated mainly in the Maritime Provinces, Quebec and Manitoba. C. sativus usually disappears from seed of wheat and barley within 3 years, but may survive in heavily infested samples as long as 9 years (23) as mycelium in the pericarp (36).

THE INFESTED SEED IN SOIL

Barley seed infested with C. sativus has dormant mycelium in the lemma, palea, pericarp, and lodicules and ungerminated spores between the lemma, palea, and pericarp (25). Because seed-borne C. sativus invades the plumule and radicle while they are still under the hull, in heavily infested seed the pathogen is soon well established. If such seed is sown, seedling blight may develop, with brown streaks on the coleoptiles and leaf sheaths, and may cause the death of seedlings. Such infested seeds have an attendant microflora the components of which are dependent on the age of the seed and its history, i.e. the growing and storage environments. The fungi isolated from seed freshly sown in soil are seed fungi. Both Christensen (9) and Mead (26) found that the soil microflora does not have a marked effect on seedling blight arising from naturally infected barley seed. The fungi isolated from freshly produced roots of wheat and barley in normal soil are soil fungi, e.g.

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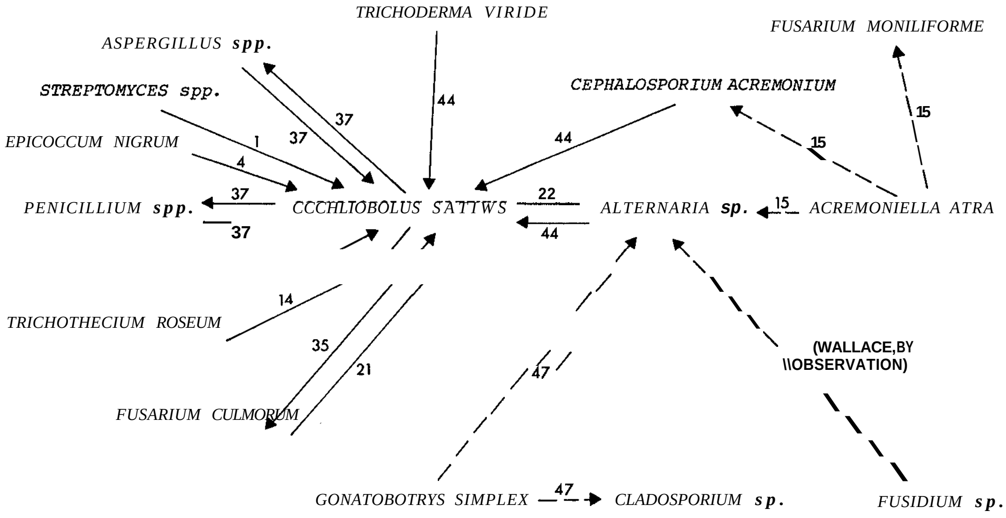

Figure 1. Possible interactions among *Cochliobolus sativus* and other fungi on cereal seed and in soil; numbers refer to Literature cited; ——▶ = inhibition, e.g. *Streptomyces* spp. are known to inhibit *C. sativus*; – – –▶ = dependence, e.g. Gonatobotrys is dependent on *Alternaria* sp. for growth.

Pythium, *Fusarium*, *Cylindrocarpon* species, and are not seed fungi (34). However, it appears that seed-borne fungi can reduce the coleoptile streaking caused by *C. sativus* (10). When surface-sterilized wheat seeds were inoculated serially with *C. sativus*, *Epicoccum nigrum* Lk. and *Alternaria tenuissima* (Fr.) Wilt., streaking caused by *C. sativus* was reduced by the antagonistic action of *E. nigrum* on the pathogen and by stimulation of the host by *A. tenuissima*. Csuti et al. (10) also found that the fungus which is applied first to the host dominates fungi inoculated later, which remain secondary.

Volatile fungicides, e.g. Panogen PX, have been tested (45) as seed treatments but they have not given complete control of the pathogen probably because of their inability to affect deep-seated infections. A more promising approach is the use of selective systemic fungicides that can kill the pathogen without altering possible beneficial effects to the seedling-from *Alternaria* spp. and other fungi.

SOIL-BORNE C. SATIVUS & F. CULMORUM AND COMMON ROOT ROT

Fusarium culmorum is commonly associated with *C. sativus* in common root rot in Canada.

In certain areas, for example northwest Alberta, *F. culmorum* is the dominant pathogen. This fungus, which has the dual role of crop pathogen and post-harvest colonizer of cereal stubble, is prevalent in the top 6 inches of the soil and has pronounced competitive saprophytic ability (3).

C. sativus occurs widely in soil or on stubble as overwintering conidia which are kept dormant by the action of soil fungistasis (40). Conidia germinate under the influence of exudates from the crown, the subcrown internode, and possibly the crown roots (S.H.F. Chinn, personal communication). Chinn has found that conidia more than 1/8 inch away from the crown will not germinate. On the Canadian prairies the subcrown internodes usually become infected in May or early June; infection subsequently extends to the crown where sporulation occurs by late July or early August and conidia drop to the soil and are later mixed by cultivation (S.H.F. Chinn, personal communication). Plants affected by root rot occur at random throughout the crop. In the post-heading phase of plant growth, premature bleaching of the ears and straw can occur. At Saskatoon Chinn (7) has studied invasion of wheat seedlings by fungi other than *C. sativus*. Possibly symptomless invasion of healthy plants, e.g. by *Penicillium* spp., interferes with subsequent invasion by *C. sativus*.

Control has been attempted with seed fungicides, by fungicidal pellets placed near the subcrown internode (29), with various soil amendments, and by certain cultural practices, e.g. incorporation of straw into soil. These attempts have met with little or no success.

Butler (3) has presented information on microfloral antagonism which has explained disease anomalies but this has achieved little in terms of disease control. He lists 846 references on root rots of which three are concerned with interrelations between root rot and insects, and one with nematodes. It is as if there has been an unwritten agreement to investigate root rots solely in terms of fungi. Insects, mites, nematodes, and other microfaunal components may affect indirectly or directly root rot incidence. These components, most abundant in the top 6 inches of the soil, are mostly microfloral grazers and some are known to feed and breed on *Alternaria* and other fungi (30).

VIRUSES AND COMMON ROOT ROT

Conceivably, root invasion by *C. sativus* and *F. culmorum* and the random distribution of common root rot across a field might be related to a virus infection, with or without evident symptoms, that predisposes plants to root rot infection. some examples of plant viruses which may affect the incidence of common root rot are as follows:

Soil-borne viruses -- Wheat soil-borne mosaic virus (WMV) and oat mosaic virus (OMV) are known to have a serious effect on yields of cereals in the USA (19) but have not been reported in Canada. In Ontario, wheat spindle streak mosaic virus (WSSMV) is known to cause significant losses in yield of winter wheat (41). Similar agents may be involved in the transmission of the three viruses. It has been suggested that the root-inhabiting fungus *Polymyxa graminis* Ledingham could be the vector of WMV and WSSMV (41). Once it was thought that *Helminthosporium* spp. were associated with transmission of the rosette form of WMV (27).

Seed-borne viruses -- Chiko (5, 6) found seed-borne barley stripe mosaic virus (BSMV) in 22% and 34% of the 2-row barley fields surveyed in Manitoba in 1970 and 1971, respectively. The incidence of diseased plants in these fields generally varied from a trace to 5%but in certain fields up to 50% of the plants were affected. Apparently no determinations have been made to check whether BSMV is a predisposing factor in common root rot.

Aphid-transmitted viruses -- Smith (42) suggested that aphid-transmitted barley yellow dwarf virus (BYDV), widespread on the Canadian prairies, could be a predisposing factor in common root rot. This hypothesis was based on New Zealand data indicating increased pathogenicity of *Fusarium* and *Rhizoctonia* root rotting fungi on wheat plants previously infected with BYDV. Scott (38) studied the interactions between BYDV and *C. sativus* in oats and durum wheat in Illinois in laboratory and field experiments. He found that root rot symptoms were more severe under field than under laboratory conditions. In BYDV-infected plants root rot symptoms were detectable earlier and were more severe than in virus-free plants. Similarly more fungi were isolated from BYDV-infected plants.

Leafhopper-transmitted viruses and mycoplasmas -- Aster yellows causal agent (AYCA) and oat blue dwarf virus (OBDV) occur on wheat, oats, and barley in Canada and can result in significant yield losses. The aster leafhopper (*Macrosteles fascifrons* Stål) is the chief vector of AYCA and the only known vector of OBDV. No determinations have been made to check whether AYCA or OBDV are predisposing factors to common root rot.

Mite-transmitted viruses -- Wheat streak mosaic virus (WSMV) is transmitted by the wheat curl mite (*Aceria tulipae* Keifer) and is found only in the winter wheat growing areas of Ontario, Alberta, and Saskatchewan.

In summary, there is considerable evidence for increased susceptibility of virus-infected plants to root rot (12, 32, 43, 46). Some of the virus and mycoplasma diseases occurring on cereals in Canada are of widespread occurrence in wheat, barley and oats (OBDV, BYDV, AYCA), others occur in restricted areas or on particular cereals (WSMV, WSSMV, BSMV). No determinations have been made to check whether any of these diseases are predisposing factors in common root rot of cereals in Canada.

SOIL MICROFAUNAL COMPONENTS AND COMMON ROOT ROT

Evidence for the involvement of microfauna in the common root rot disease syndrome has been presented by Hanson et al. (18) who found that the bluegrass billbug, *Calendra parvula* (*Sphenophorus parvulus* Gyllendal), was widely distributed in eastern North Dakota, Nebraska, Minnesota and other north-central States of the United States. This weevil attacks the lower internodes of stems and sometimes the roots of spring wheat, barley, and grasses, weakening the plants and making them more vulnerable to attack by root rot organisms. Also, it provides avenues of entrance for these pathogens, and both adults and larvae of the insect carry fungi and bacteria in and on their bodies. So far there have been no reports of involvement of this insect with common root rot on the Canadian prairies.

Burrage and Tinline (2) at Saskatoon treated wheat seed with gamma BHC, aldrin, and heptachlor and found in field tests that root rot frequently was greater in plants from untreated seed than in those from seed treated with most of the insecticides tested, possibly because of damage to the untreated plants by wireworms. However, wireworms, while locally abundant, are not a problem in most fields on the Canadian prairies (S.H.F. Chinn, personal communication).

Some microfaunal types are found in most wheat fields, for example, Collembola, mites, and nematodes. They are mobile, have a discontinuous distribution in soil, and can increase quickly to large numbers if a suitable food source is present (28). Interactions that could occur between microfloral and microfaunal components in a

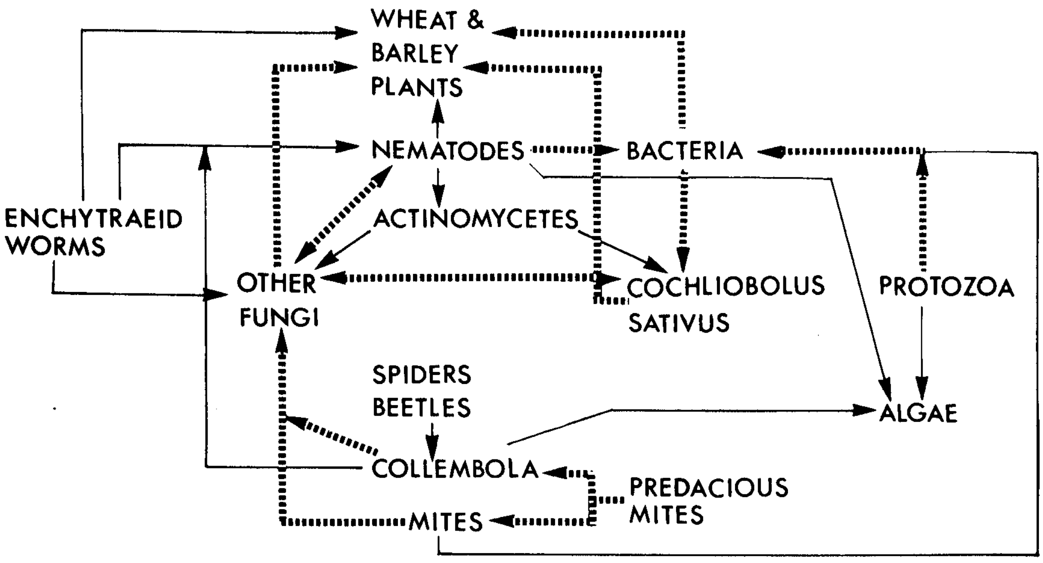

Figure 2. Possible interactions among *Cochliobolus sativus* and other biota. Solid lines indicate inhibition, broken lines indicate dependence.

soil infested with C. sativus are depicted in Fig. 2. Possibly C. sativus is affected indirectly; for example microfaunal components may eat fungi or bacteria antagonistic to C. sativus. Also, some nematodes eat bacteria and thus could interfere with bacterial lysis of C. sativus spores. In addition, some nematodes penetrate roots and thus allow fungi antagonistic to C. sativus to enter, excluding the pathogen by physical occupation of space. A further consideration is the dispersal of spores by mites and Collembola. Collembola feed on fungi and bacteria including components antagonistic to the pathogen. They migrate vertically downwards under adverse weather conditions, e.g. drought, and flourish in moist soil (17). In years of high rainfall there is a lower incidence of common root rot and this may be related in some way to the soil microfaunal components remaining near the surface.

CONTROL OF COMMON ROOT ROT OF CEREALS WITHIN THE TOTAL SOIL ECOSYSTEM

The total soil ecosystem and the abiotic and biotic factors operating within it, are depicted in Fig. 3. The phases in the life cycle of C. sativus related to the

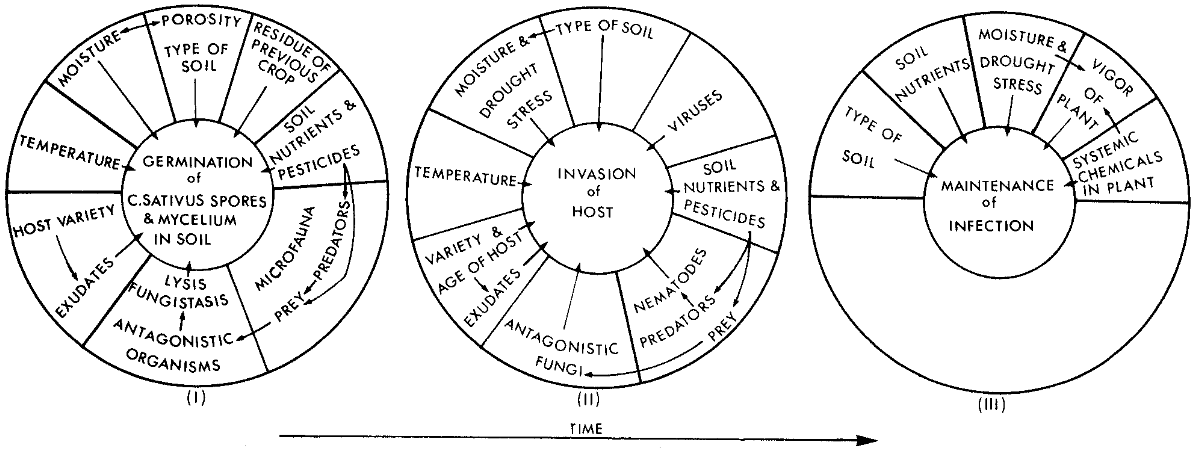

Figure 3. Most important variables affecting *Cochliobolus sativus* in soil and development of root rot in cereal plants with time.

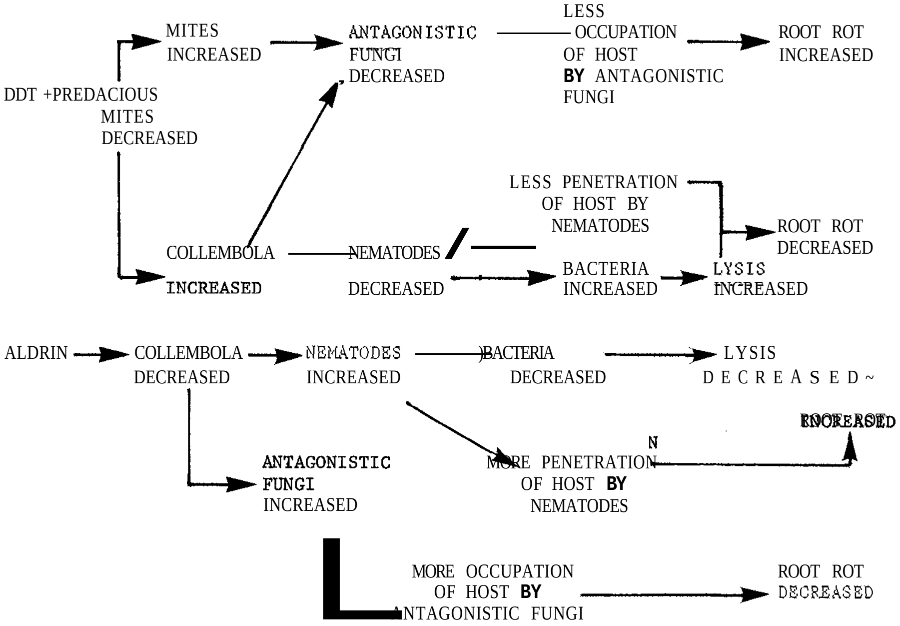

Figure 4. Theoretical pathways showing how the insecticides DDT and aldrin could affect incidence of root rot of cereals.

development of common root rot in soil are probably governed by only a few of these factors which vary with time. Control of common root rot can best be achieved at the stage of invasion of the host (Fig. 3 ii). We need to concentrate on the modifying factors and interactions among them, so that any recommended management practices will not indirectly favor the fungus. Fig. 4 shows two examples of how pesticide management practices may affect root rot via several possible pathways. Selective and wide-spectrum pesticides have already been used (16) for sorting out causal agents of soil-borne plant diseases. Each part of each interaction in the pathways could be monitored in the laboratory, e.g. changes in microfaunal populations. Similarly increases in *Streptomyces* when plants are sprayed with 2, 4-D, could be checked out using media selective for *Streptomyces*. Once validated in the laboratory, interactions may be studied in barley or wheat fields with a known history of severe root rot. Replicated strips of barley or wheat could be treated with pre-emergence or post-emergence herbicides, insecticides, acaricides, and fungicides. Microfloral and microfaunal populations and virus occurrence should be monitored at intervals, and root rot at maturity. In this way, involvement of microfauna and viruses in root rots may be determined. This information may lead to a practical means of control. Once the disease is controlled successfully, treatments can be modified where necessary to nullify possible harmful ecological effects. If microfauna and viruses are not found to be involved then we can look at the other (Fig. 3 ii) modifying variables.

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