Plant Disease Fungi In Sewage Polluted Water

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THE plant pathologist is characteristically interested in the source of infectious agents of the many plant diseases with which he has to deal. Of crops which have been under cultivation for long periods of time, the various diseases to which they are subject seem to be as old as the host plant. These diseases may be with the host at all times (systemic), or they may be carried by the host seed. They may overwinter on dead plant tissues on the ground, complete their life cycle in the spring, and reinfect the host at that time. Or they may overwinter in the soil as members of the extensive population of soil micro-organisms in dead plant tissue or as resting spores or cells in the soil.

It has long been known that many fungal spores can be carried from a locus of spore production to an infection site by the wind. Some of those which are airborne may incidentally cause allergies; others may settle out of the air in places where their activities are undesirable, causing food and material spoilage.

Water has not been considered seriously as a means of disseminating plant disease spores. Spores which settle out of the air into water and are carried impassively to another point may not reproduce in the water and are not considered of importance in this medium. An obligate parasite such as rust or powdery or downy mildew is not known to have spores capable of germination and growth in water. Soil fungi are known to have spores which are carried in streams, but these are thought to be contaminants, and serious attention is not paid to the possibility of their germination and reproduction in liquid menstruums.

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Sewage Irrigation

The literature of sewage and waste disposal contains many references to the use of sewage as a source of supplemental irrigation water. References are increasing as studies are made in drier parts of the country where sewage and other wastes can be of increasing use in reclamation of water. Skulte (*1*) states: "Skillfully designed and properly managed sewage farming has been operated for decades in Europe, and for several years in some localities in the southwestern areas of the United States, without danger to personnel and without creating nuisance conditions. As a new science, irrigation with sewage effluent is still in the experimental stage and many problems need to be solved in the fields of bacteriology, biology, hygiene, soil structure, and the physiology of plants."

State and Federal agencies have been interested for many years in the use of sewage as an irrigation supplement. According to Hunt (*2*) most communities in the United States could use supplemental irrigation during annual periods of drought. Methods of reclaiming sewage for re-use in irrigation have been described by Hutchins (*3*) and are being studied in California by Bush and Mulford (*4*) and Merz (*5*). Water, the Yearbook of Agriculture for 1955 (*6, 7*), contains several articles by Department of Agriculture and Public Health Service personnel, showing an undercurrent of interest in this problem. On the research level, certain recent studies indicate some of the problems involved. The effect of spreading rather than furrowing in irrigation technique has been investigated by Bush and Mulford (*4*) and by Greenberg and Thomas (*8*). A study by Henry and associates (*9*) was designed to indicate the influence of sewage waters on mineral content, organic content, soil structure, and other aspects of soil quality. In such studies it has been found that the most important mineral problem is that of sodium which sewage seems to add to soils.

In a popular article by Stone (*10*), it was pointed out that sewage could be used for a number of irrigation purposes. Besides irrigating crop plants, it could be used for irrigation of lawns and ornamental plantings. Illustrations of several types of use are given in his article.

In his Biology of Root-Infecting Fungi, Garrett (*11*) sums up his thesis with a statement to the effect that, until a crop is grown in a soil free from disease infestation, one cannot appreciate the exceptionally healthy nature of the plants which produce that crop or the losses in crop values of diseased plants. We may assume that this consideration can also apply to soils into which disease organisms, however unapparent they may be, are dumped on a periodic and perhaps daily schedule.

Menzies (*12*) has pointed out that certain plant pathogens have become more and more a problem to the plant pathologists as the practice of irrigation increases in the Columbia Basin. Those pathogens mentioned are airborne leaf and fruit diseases rather than waterborne soil fungi and have been introduced with the crop or have migrated to the spot in much the same manner as other rusts, mildews, and host-restricted pathogens. His forecast that other diseases could become important in the region is of interest.

Prior to 1952 the presence of fungi in polluted waters and sewage was considered by most workers in the field of sanitary science to be an established fact but not worthy of special investigation. It was obvious that under certain conditions of pollution a stream or a trickling filter would develop growths which were thought to be fungi and were identified to species in occasional studies (*13*). No reference to the isolation or identification of plant pathogens as such from raw sewage or partially treated waters has received our attention.

Aqueous Acclimatization

The routine study of a small polluted stream, of a secondary-type sewage treatment plant at Dayton, Ohio, at monthly intervals, and of other habitats at less frequent intervals yielded quantitative and qualitative data concerning the presence of soil fungi in these habitats (*13*). Various media were tested and techniques used that are common to the study of soil microbiology. From these studies it appears that certain strains of species of soil fungi have become acclimated to living in aqueous habitats. Spore production is atypical when present, and certain tested species are able to use dissolved oxygen in competition with other sewage organisms for reduction of organic materials (*14*). Most of the species tested are able to produce their own vitamin supply, and all are able to utilize simple sugars and organic as well as ammonia nitrogen.

Some of the fungi isolated from sewage polluted water are listed in the table, together with some of the diseases of crop and ornamental plants which are attributed to them. Some of the species were isolated only once or rather infrequently. Other species were very common, and some appeared in a large number of samples tested for fungi. In some cases these fungi were found only on trickling filters in a sewage treatment plant, indicating that other habitats in the plant, such as Imhoff tanks, secondary sludge digesters, preaeration tanks, and so forth, were not favorable habitats for their survival. Seasonal distribution is sometimes apparent because certain species are found only in 1 or 2 seasons of the year.

Garrett (*11*) considers seedling blight and vascular wilt fungi as "ecologically obligate parasites"; that is, while they are able to grow alone or in competition with other fungi on culture plates, in the soil they appear to be unable to compete with strictly saprobic fungi for the dead organic matter present there. On the other hand, there is evidence that in sewage and related habitats they can reproduce, as indicated by observations on the degradation of hydrocarbons.

Strains From Domestic Sewage

Strains of both *Fusarium oxysporum* and *Fusarium solani* have been recovered at one time or another from domestic sewage. To determine the degrading ability of sewage organisms for various types of industrial wastes such as hydrocarbons, domestic sewage was seeded into experimental materials (*15*). During the period of observation of one experiment, two groups of organisms developed in large quantities, a protozoan and a strain of *F. oxysporum*. In a later experiment this strain was added to a suspension of motor oil in dilution water. After 3 weeks the fungus had produced almost as much breakdown of the oil as had domestic sewage tested at the same time in similar solutions. Similar sewage seed was used to develop a slime on an experimental trickling filter in which hydrocarbons of airplane cleaning materials were treated. Upon plating the slimes it was found that a strain of *F. solani* was the predominant fungus present.

Plant diseases caused by some fungi isolated from sewage-polluted waters

Fungus	Disease
Alternaria tenuis	Leaf spot of cotton, seed mold of brome, seed mold and secondary leaf spot of buckwheat, other diseases of other hosts.
Aspergillus niger	Fig smut, date smut, black mold of onions.
Botrytis cinerea	Black rot and leaf blight of lettuce, storage rot of sugar beets, other diseases.
Cephalosporium spp	Diseases of soybeans, celery, sugar cane, and other plants.
Chaetomium funicolum	Seed mold.
Chaetomium globosum	Seed mold.
Cladosporium cladosporioides.	Seed mold.
Coniothyrium fuckelii	Canker of apple, graft canker of rose.
Curvularia lunata	Brown spot of gladiolus.
Epicoccum nigrum	Glume spot, smudge of wheat.
Fusarium moniliforme	Seedling blight of oats, secondary root rot of barley, ear rot of corn.
Fusarium oxysporum forms	Root infections of such plants as: celery, China aster, onion, cabbage, gladiolus, flax, tomato, alfalfa, muskmelon, watermelon, peas, narcissus, sweet potato, spinach, bananas.
Fusarium solani forms	Among other plants, onions, sweet peas, peas, potatoes.
Penicillium digitatum	Blue mold rot of citrus fruit.
Penicillium expansum	Blue mold of oats, barley, broom corn, millet, wheat, apples.
Penicillium italicum	Blue mold rot of citrus fruit.
Penicillium oxalicum	Seedling blight of corn, mold of corn grains and cobs.
Trichoderma viride	Seed rot of corn and barley, seed mold of wheat, green mold rot of muskmelon.

In certain communities, sewage in various stages of treatment is used as a source of irrigation supplements. The raw sewage can contain fungal spores introduced from such sources as runoff from soils following precipitation or lawn and flower bed irrigation, washings from infected or moldy plant parts, mildewed materials, or contaminated plumbing, where growths can occur between intermittent flow periods. In other communities, effluents from primary settling tanks or Imhoff tanks are used, and in some cases secondary treatment processes may be bypassed. In still other communities, effluents from complete or secondary treatment plants may be employed. Depending on the type of treatment, that is, whether recirculation is practiced or whether the plant is overloaded, the effluent may be rich or poor in fungus disseminules. Seasonal activity within the treatment plant or in the various places from which its populations are derived could give a seasonal pattern to the micro-organisms in the effluent. The sludges used for supplemental fertilizers or soil conditioners may have developed a population of organisms that could produce trouble in the field or at least add to the populations of micro-organisms in the field awaiting favorable conditions for infecting crop plants.

Contamination of Plant Parts

Not only are crop plants growing in the field subject to inroads by fungus disease, but the products of such crops may become infected by fungi. Seeds and grains may become contaminated by fungi during or after harvest, and in some cases spores of disease-producing fungi may be formed together with the seeds to which they adhere, thus supplying inoculum for infecting the seedling. Succulent plant parts may become infected by soil fungi, or by fungi existing in the soil capable of infecting only such plant parts. These include leaves, shoots, petioles, tubers, roots, and other similar edible plant parts harvested for domestic use. The flowers and fruits of many crop plants can readily become infected with fungi growing or existing in the soil. All plant parts may be subject to additional infection from fungi added to the soil in sewage polluted waters used as irrigation supplements. These fungi can become a great problem and produce tremendous losses before the foods which have been harvested reach the consumer since, under improper conditions of transport, storage, warehousing, and marketing, large numbers of fruits and vegetables can be lost by spoilage. The cycle can be repeated when the waste produce is discarded into the sewerage system and the inoculum present is added to the organisms growing in various parts of the sewage treatment plant, or to that present in the soil if the sewage is applied to the field.

The paradox of the situation is that under certain circumstances a fungus that could cause considerable damage in a field could be actively purifying the sewage in which it is living. Should a treatment for such wastes be developed in which fungi were the principal microbiological agents, and should the effluents containing spores or other disseminules be applied as irrigation supplements indiscriminately, it is likely that an inoculum for disease of a crop plant could develop.

It thus appears that in these days of increased supplemental irrigation by use of sewage and polluted water, the plant pathologist and the public health official are confronted with additional problems of disease control. Unfortunately, the control of one fungus chemically may inhibit the work of many beneficial organisms; hence, control measures necessary for irrigation waters should be applied to effluents rather than to influents of the sewage treatment plant. It is possible that adequate control of plant pathogens may also result in adequate control of human pathogens, so that a wider use could be made of sewage effluents than is being made today.

The role of fungi added to the soil by sewage-polluted irrigation waters in contributing to crop and plant infections certainly merits attention.

REFERENCES

(*1*) Skulte, B. P.: Irrigation with sewage effluents. Sewage & Indust. Wastes 28: 36–43, January 1956.

(*2*) Hunt, H. J.: Supplemental irrigation with treated sewage. Sewage & Indust. Wastes 26: 250–260, March 1954.

(*3*) Hutchins, W. A.: Sewage irrigation as practiced in the Western States. U. S. Department of Agriculture Tech. Bull. No. 675. Washington, D. C., U. S. Government Printing Office, 1939, pp. 1–59.

(*4*) Bush, A. F., and Mulford, S. F.: Studies of "waste water reclamation and utilization." California State Water Pollution Control Board Publication No. 9. Sacramento, 1954.

(*5*) Merz, R. C.: A survey of direct utilization of waste waters. California State Water Pollution Control Board Publication No. 12. Sacramento, 1955.

(*6*) United States Department of Agriculture: Water. The yearbook of agriculture, 13th. Washington, D. C., U. S. Government Printing Office, 1955.

(*7*) Schwab, C. E.: Pollution—A growing problem of a growing nation. *In* Water. The yearbook of agriculture, 13th. Washington, D. C., U. S. Government Printing Office, 1955, pp. 636–643.

(*8*) Greenberg, A. E., and Thomas, J. F.: Sewage effluent reclamation for industrial and agricultural use. Sewage & Indust. Wastes 26: 761–770, June 1954.

(*9*) Henry, C. D., Moldenhauer, R. E., Engelbert, L. E., and Truog, E.: Sewage effluent disposal through crop irrigation. Sewage & Indust. Wastes 26: 123–133, February 1954.

(*10*) Stone, R.: Irrigation with waste waters. Pub. Works 86: 97–98, 134–135, November 1956.

(*11*) Garrett, S. D.: Biology of root-infecting fungi. New York, Cambridge University Press, 1956.

(*12*) Menzies, J. D.: Plant disease observations in the irrigated areas of central Washington during 1953. Plant Disease Reporter 38: 314–315 (1954).

(*13*) Cooke, W. B.: Fungi in polluted water and sewage. I. Literature survey. II. Isolation technique. III. Fungi in a small polluted stream. Sewage & Indust. Wastes 26: 539–549; 661–674; 790–794; April–June 1954.

(*14*) Cooke, W. B., Moore, W. A., and Kabler, P. W.: Comparative satisfaction of B. O. D. by fungi in pure culture and in competition with domestic sewage seed. Sewage & Indust. Wastes 28: 1075–1086, September 1956.

(*15*) Ludzack, F. J., and Kinkead, D.: The persistence of oily wastes in polluted water under aerobic conditions. Motor oil class of hydrocarbons. Indust. Eng. Chem. 48: 263–267, February 1956.