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Microbiological Aspects of Phytotoxicity in Soil

by

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Introduction : It is a well known fact that organic constituents of soil can improve plant growth. But are there organic compounds in soils called ("Toxins") which are detrimental to plant growth? This question has occupied the minds of workers interested in crop production for a number of years. There was considerable controversy among research workers during the early nineteen-hundreds about the existence of toxins; it is now fairly well accepted that there are substances in soil which, under certain conditions, can be harmful to plant growth. These organic compounds or phytotoxic compounds in soils and plants have been isolated and studied using new techniques such as paper, gas and column chromatography and infra-red spectrophotometry. The purpose of this paper is to review research on microbiological decomposition products and organic substances in plant and soil residues which are known to be inhibitive to plant growth. An attempt has been made in this paper to review all the literature available so far on this subject.

Toxic Factors in Soils : The application of organic chemistry to the study of toxic substances in soil came with Schreiner and his team workers of the U.S. Department of Agriculture. They isolated a large number of substances from the organic fractions of the soil, but in those soils where the fertility had been reduced by over-cropping. Four main constituents were identified and they were dihydroxystearic acid, picolinic acid, salicylaldehyde and vanillin. Schreiner and Reed (1908) grew successive crops of wheat in the same container and found wheat yields decreased and root growth impaired. However, Schreiner and Skinner (1910) showed that the harmful effect dihydroxystearic acid could be overcome by adequate fertilization of the plant.

Thus we see that the problem of soil toxicity seems to be ubiquitous. In Southern and Western Australia the failure of crop and pasture establishment has been attributed to soil toxins (Harris, J. R. personal communication). In Canada, the failure of apples and peaches to grow satisfactorily as replants have been shown to be caused, in part, by the formation of phytotoxin compouuds through microbial decomposition of the roots. (Patrick, and Koch, 1958; Borner, 1958, 1959, 1960). In California, U. S. A., the slow growth of citrus seems to be a related case of soil toxicity for which the active principle has not yet been identified. In France (Cochrane, 1949) reported the toxic effect of crop residues on the growth of lettuce roots.

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Plant Residues as Growth Inhibitors: Plant residues provide the most abundant source of these growth inhibitors in soil. The toxins can be present as such and be leached out by water; they can be formed though microbial decomposition of plant residues or they can be synthesized by soil microflora. Cereal culture is attended by the problem of disposal of straw waste as well as the unseen underground portions of the plant. As early as 1925 Collison reported inhibitory substances in wheat straw. More recently the German investigators (Winter and Schonbeck, 1953, 1954, 1957) have demonstrated water soluble substances in roots and straw of barley, rye, wheat and oats which had inhibitory effects upon wheat roots at concentrations as high as 1 in 400. Borner, (1955, 1956a 1956b) has identified a number of compounds in aqueous and alcoholic extracts of straw and roots and these include phenolic phytotoxins, notably, *p*-coumaric acid, ferulic acid, *p*-hydroxy-cinnamic acid, vanillic acid and *p*-hydroxy-benzoic acid. These compounds have been synthesized and shown to inhibit the growth of rye and wheat roots in water culture.

It has been suggested (McCalla and Army 1961; McCalla and Haskins 1964; Patrick, Toussoun, and Koch, 1964) that the adverse effects of crop residues left lying on the surface are due, at least in part, to a phytotoxic substance(s) produced by the rotting crop residue. In an earlier work, Myers and Anderson (1942) claimed that the stunting of growth is due primarily to microbial immobilization of nitrogen which then becomes unavailable to the plant. The increased activity of pathogens promoted by the moist conditions maintained by the straw layer has also been suggested as a contributing facter (Garrett, 1956).

Although the last two possible reasons for poor growth of crops may be significant, and certainly the effect of nitrogen immobilization is well supported there exists nevertheless a wealth of evidence suggesting that phytotoxicity is a very real factor. There are many examples in the literature of water extracts of grass residues being toxic to plants (Doran, 1921; Patrick and Koch, 1958). Also Guenzi and McCalla, (1962) have shown than aqueous extracts of unrotted cereal straws as well as wheat straw rotted for different periods have been shown to inhibit the growth of wheat and oats grown under asceptic conditions. The degree of inhibition varied with the time of rotting and was maximum after 2-6 days (Kimber, 1967). Amin and Sequira (1966) also detected phytotoxic substances in soils amended with lettuce crop residues. The identified one of the toxic components to be *m*-ethylaminobenzoic acid.

Organisms Involved in Causing the Toxic Effect: Soil microorganisms produce a tremendous variety of organic substances during the decomposition of plant and animal residues, and, as numerous studies have shown, some

of these substances are phytotoxic. Swaby (1942) found that, when soil microorganisms were present in association with plant residues (Lucerne and *Phalaris tuberosa*), substances inhibitory to plant growth were frequently produced.

In U S.A. stubble mulch practices have been widely employed to overcome soil erosion, but leaving crop residues on the surface suffers from the defect that plant growth and grain yield is reduced in wet years. McCalla *et al* (1963) studying the decomposition of crop residues isolated a strain of *Penicillium urticae* which produced phytotoxic substances in culture media, and these caused curling and dwarfing of seedling root growth. This has now been identified as the antibiotic patulin. Wright (1956) has recorded the production of gliotoxin in buried wheat-straw. Mirchink and Greshnych (1961) have recorded toxicity in uncultivated podzols to be high due to the fungal population and have recognised the antibiotics patulin, gliotoxin etc., being produced from species of *Penicillium* and *Aspergillus*. There is, in fact, a copious literature on the production of antibiotics in soil and their effects on plants for which the works of Krasilnikov (1958) may be consulted. In Japan, the poor shoot growth of rice under soils of low fertility has been attributed to *Clostridium* (Takijima, 1962). It is now known that normal intracellular or surface microflora of green plants mainly *Aerobacter aerogenes*, *A. cloacae* and *Escherichia coli* are responsible for the breakdown of plant residues resulting in the formation of phytotoxins (Fraser *et al* 1956; Duncan *et al* 1964; Iswaran *et al* 1968).

Phytotoxicity of Seed Exudates: The presence of a substance toxic to nodule bacteria in clover seeds was first demonstrated by Thompson (1960) who showed that the agent responsible was confined to the seed-coat and could be extracted there-from by water. Quercetin (3, 5, 7, 3, 4' - pentahydroxy flavone), was found in those seeds containing myricetin but at a lower concentration. Toxicity was found to be proportional to the amount of toxin present. The toxicity can be reduced by including small quantities of metal salts in the growth medium (Masterson, 1965). Similar claims have been made by many workers. In the present review it is not possible to cover this aspect of phytotoxcity in detail. Interested workers can go through papers by (Bowen, 1961, Lobb 1958; Maruzzella *et al* 1959).

Summary and Conclusion: A wide variety of phytotoxic substances exist in soils, plant residues and seeds. The presence of these substances may account in part for adverse effects of a particular crop on a succeeding crop in crop rotations. Perhaps the most challenging aspect of soil toxicity to the microbiologist will be whether he will be able to find soil organisms which can

be introduced into sown seed adjacent to the roots. If this can be done, inoculation for detoxication may become one of the major contributions of soil microbiologist for agriculture.

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