APPENDIX E
ANNOTATED BIBLIOGRAPHY ON THE EFFECTS OF PESTICIDES ON NONPHOTOTROPHIC MICROORGANISMS OF RICEFIELDS

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This annotated bibliography presenting ninety-five references dealing with the effects of pesticide on ricefield microflora. Papers selected include:

- All papers dealing with the effects of pesticides on nonphototrophic micro-organisms and microbial activities and reporting studies in ricefields, with ricefield soil, or with strains isolated from ricefields or known to be present in ricefields;
- Few papers of interest for methodological aspects or presenting data useful for comparison; and
- Bibliographic reviews including references on wetland soils.

The following code is used:

(NS)	(No summary) The original paper has no summary.
(NC)	(Not consulted) The paper was not available and is cited from another paper.
Abstract:	The document cited is only an abstract, not a full paper.
Summary:	The summary or abstract is included in the original paper.
Notes:	Short summary or comments by the author of this compilation.

Akhtar, S., Solangi, H., Baig, M.M.H. (1986) Effect of DDT on soil microorganisms isolated from Punjab paddy field. *Pakistan J. Sci. Ind. Res.* 29(6): 444–447.

Summary: Comparison between the application of DDT technical 70 percent and DDT formulation 50 percent WP at recommended dose (1 kg/ha) indicates a similar level of retardation of microbes, showing only 20–30 percent growth as compared to control. Tolerance study indicate that *B. apairius* and *S. epidermis* can stand formulations up to 200 times higher than the normal field application rate, whereas, *B. megaterium*, *B. subtilis*, and *B. circulans* showed minimum tolerance to DDT's normal field application rate.

Notes: Inoculation of soil suspension dilution on agarized medium in petri dishes. At the recommended dose (1 kg ai/ha) DDT had no significant effect on five strains and reduced growth of three probably by more than 50 percent.

Anderson, J.P.E., Armstrong, R.A., Smith, S.N. (1981) Methods to evaluate pesticide damage to the biomass of the soil microflora. *Soil Biol. Biochem.* 13(2): 149–154.

Summary: Respiratory methods to estimate the amount of C in the soil microbial biomass and the relative contributions of procaryotes and eucaryotes to the biomass were used to evaluate the influence of pesticides on the soil microflora. Experiments were conducted with 5 and 50 μg/g of three fungicides, captan, thiram and verdasan. At 5 μg/g they caused significant decreases (40 percent) in the biomass; the organomercury fungicide verdasan also caused a shift from fungal to bacterial dominance. Within eight days, biomass in captan- and thiram-amended soils had recovered to that of the controls. Although the fungal to bacterial balance was restored in verdasan-amended soils, biomass recovery was not complete. At 50 μg/g the fungicides caused long-term decreases in the biomass and altered the relative proportions of the bacterial and fungal populations. Verdasan had the greatest effect on soil microbial biomass and composition.

Notes: Deals with upland soil. Respirometric methods useful in upland soils are much less suitable for submerged soil where both methane and CO_2 are produced.

Anderson, J.R. (1978) Pesticide effect on non-target soil microorganisms. Pages 313–533 in Hill, I.R., Wright, S.J.I., (eds.), *Pesticide microbiology*. Academic Press, London. (NS)

Notes: This review deals mostly with upland soils. It covers work published between 1965 and 1976. It includes more than 500 references and tabulated data of pesticide effects over 118 pages.

Among a total of 1,016 records of effects, only 11 deal with rice soils; 920 records deal with herbicides, 20 with fungicides, and 76 with insecticides.

Azad, M.I., Khan, A.A. (1968) Studies upon the reduction of nitrogen losses through denitrification from paddy soil by the application of pesticides. *West Pakistan J. Agr. Res.* 6(4): 128–133.

Summary: The studies were carried out in the laboratory of the Chemical Section, Agricultural Research Institute, Tarnab, Peshawar under controlled conditions. The data reveal that both the chemicals proved themselves partially inhibitive for denitrifiers. The detrimental effect of the chemicals on denitrifiers increased with the increase in the concentration in application rates and decreased with the increase in duration. The results suggest that a constant application of both the chemicals (Endrin and Dimecron) at the rate of 25 ppm at fortnight intervals to paddy soil will reduce the nitrogen losses caused by denitrification process to a great extent.

Notes: Experiment with 100 g of soil in flasks

Baruah, M., Mishra, R.R. (1986) Effect of herbicides butachlor, 2,4-D and oxyfluorfen on enzyme activities and CO_2 evolution in submerged paddy field soil. *Plant Soil* 96(2): 287–291.

Summary: Effects of three herbicides 2,4-D, butachlor and oxyfluorfen on activities of dehydrogenase, urease and carbon dioxide evolution from paddy field soil were measured on weekly intervals. Dehydrogenase activity was significantly stimulated on application of herbicides. The herbicides did not affect the urease activity and the activity remained almost unchanged. The carbon dioxide output was higher in herbicide treated soil.

Brungs, W.A., Mount, D.I. (1978) Introduction to a discussion of the use of aquatic toxicity tests for evaluation of the effects of toxic substances. Pages 15–26 in Cairns, J. Jr., Dickson, K.L., Maki, A.W. (eds.), *Estimating the hazard of chemical substances to aquatic life*, ASTM STP 657, American Society for Testing and Materials.

Summary: A variety of classes of aquatic toxicity tests are presented and discussed in relation to their ability to provide useful estimates of the environmental effects of chemicals or discharges. These classes of tests can be judged and compared numerically by several standards: ability to permit extrapolation to meaningful effect; ease and cost of conducting tests; applicability to response to a wide variety of chemicals; availability of documented detailed procedures; ecological importance and persistence of effect; and scientific and legal defensibility of the procedure. No single class of tests can be expected to be clearly superior to all others, indicating the need for a variety of testing at successive tiers of intensity of study.

Chao, C.C. (1983) Effects of insecticides on the population of soil microorganisms and crop growth. *J. Agric. Assoc. China* 124: 89–98.

Summary: In this study, endeavors were made to investigate the effects of insecticides, Methomyl and Monocrotophos on the growth and function of various soil microorganisms and plants in pot experiments. They were applied individually in the pots at the concentrations ranging from 1, 5, 10, to 100 times of the field recommended rate. The microorganisms studied were the urea-hydrolyzing organisms, the heterotrophic nitrogen fixers, the nitrifiers, some heterotrophic bacteria and fungi. The two plants employed were corn and rice for upland and paddy-soil experiments respectively. The toxicity of Methomyl to the nitrifiers manifested in four days and to the heterotrophic bacteria in two weeks. However, it promoted the growth of the urea-hydrolyzing organisms and fungi two weeks after the addition of pesticide. The chemical had no effect on the nitrogen fixer, *Azotobacter* sp., but for corn it was a potent poison, especially as the dose reached 100 times of the normal rate. It did not stunt the growth of plant, but it lowered the kernel yield. To the soil microbes and rice plant, Monocrotophos was rather mild. Its use, even at the dosage 100 times above normal rate, caused rice no ill consequences. The growth of the heterotrophic bacteria and *Azotobacter* sp. was hampered by the chemical in the first two weeks of spraying, but afterwards they soon recovered. Monocrotophos was not toxic to fungi, and was even stimulatory to a minor degree for the urea-hydrolyzing organisms.

Charyulu, P.B.B.N., Ramakrishna, C., Rao, V.R. (1980) Effect of 2-aminobenzimidazole on nitrogen fixers from flooded soil and their nitrogenase activity. *Bull. Environ. Contam. Toxicol.* 25: 482–486. (NS)

Notes: 2-aminobenzimidazole is a degradation product of Benomyl. Concentration of 10, 20, and 100 ppm had either no effect or positive effects on populations of N_2-fixing microorganisms. At all concentrations, 2-aminobenzimidazole retarded the drop in Eh observed in soil after submersion.

Chen, Y.L. (1980) Degradation of butachlor in paddy fields. Pages 121–142 in *FFTC Book Series No. 20: Weeds and weed control in Asia.* Food and Fertilizer Technology Center, Taiwan. (NS)

Notes: Extensive experimental survey of all pathways of butachlor disparition from ricefields. Includes data on its effect on nitrification at different temperatures and pH. At 30°C and pH 6.8, 6 ppm butachlor simulated nitrification, soil respiration, had no significant effect on populations of fungi and actinomycetes but possibly increased total populations of bacteria for about two weeks.

Chendrayan, K., Sethunathan, N. (1980) Effect of HCH, carbaryl and atrazine on the dehydrogenase activity in a flooded soil. *Bull. Environ. Contam. Toxicol.* 24: 379–382.

Notes: Pesticides used at 1 ppm (value close to the recommended dose) had no effect on dehydrogenase activity of the soil and its redox potential.

Chopra, P., Magu, S.P. (1986) Respiration as influenced by urea herbicides in soil amended with compost. *Int. J. Trop. Agric.* 4(2): 137–142.

Summary: Under laboratory conditions, soil respiration was inhibited by tribunil (0.5 to 5 ppm) and isoproturon (0.35 to 3.50 ppm) at fifteen and thirty days of the incubation. The incorporation of 0.5 percent w/w paddy straw compost with different doses of tribunil mitigated the toxicity at thirty days. However, in case of isoproturon, the amelioration was observed only with 0.35 ppm. Under wheat crop, isoproturon reduced carbon dioxide evolution at ten weeks of plant growth. However, the toxicity of the herbicide was reduced in the presence of paddy straw compost. At sixteen weeks (harvesting stage) soil respiration was observed to increase significantly in all doses of both isoproturon (0.35, 0.70, 1.40 ppm) and tribunil (1.0, 2.0, 5.0 ppm) treated with compost.

Notes: Pot experiment with non submerged soil planted with wheat.

Chowdhury, A.K., Mukhopadhyay, A.K., Mukhopadhyay, S. (1972) Influence of certain herbicides on the fungal populations in soils. *Indian Phytopath.* 25: 188–194.

Notes: Cited in Anderson (1978). Propanil at 2, 3, and 4 kg/ha, Nitrofen at 2, 4, and 6 kg/ha, and Prometryne at 0.25–1.0 kg/ha caused a transitory decrease of populations of *Aspergillus* and *Fusarium*.

Cooper, S.L., Wingfield, G.I., Lawley, R., Greaves, M.P. (1978) Miniaturized methods for testing the toxicity of pesticides to microorganisms. *Weed Rese.* 18: 105–107.

Summary: A miniaturized method of determining the toxicity of pesticides to a large number of soil microorganisms is described. Bacteria, actinimycetes, yeasts, fungi, and algae can be used as test organisms. A modification of the methods allows determination of minimum inhibitory concentration of pesticides to specific microorganisms. Some results obtained with herbicides are presented.

De, B.K., Mukhopadhyay, S. (1971) Effect of MCPA and Stam F-34 on the occurrence of some nutritional groups of bacteria in the ricefields of west Bengal. *Int. Rice Commn. Newsl.* 220: 35–39.

Notes: Cited in Anderson, J.R. (1978). Study with a West Bengal ricefield soil. Propanil at 3.14 and 5.3 kg/ha decreased populations of nitrifiers. At 10.5 kg/ha it caused a large decrease in denitrifiers and denitrification. At 10.2 and 17.1 kg/ha it decreased cellulolytic populations. MCPA at 2.25 kg/ha caused a large decrease in denitrifiers and denitrification.

Endo, T., Kusaka, T., Tan, N., Sakai, M. (1982a) Effect of the insecticide cartap hydrochloride on soil enzyme activities, respiration and nitrification. *J. Pest. Sci.* 7: 101–110.

Summary: The effect of cartap hydrochloride (cartap-HCI; Padan) on soil enzyme activities, respiration and nitrification were examined for thirty or sixty days in laboratory-conditioned upland and flooded soils. Cellulase and saccharase activities were not influenced, even by 1,000 ppm treatment in either conditions. Phosphatase activity in 1,000 ppm treatment decreased but the recovered. Protease activity under flooded conditions was depressed by 1,000 ppm treatment during the first fifteen days, but became higher than in the untreated soil after thirty days. This activity under upland conditions decreased in the 100 and 1,000 ppm treatments over the entire sixty-day period. Oxygen uptake was retarded by 1,000 ppm treatment during thirty days but it subsequently recovered. In the soils treated with cartap HCI at 100 and 1,000 ppm, NH_4-N accumulated but NO_2–N and NH_3–N diminished. These findings suggest that nitrifying organisms were affected by high concentrations of Cartap HCI. All of the four enzymes activities, respiration and nitrification showed very little changes at normal application rates (10 ppm) of the chemical in the soil under upland and flooded conditions.

Endo, T., Kusaka, T., Tan, N., Sakai, M. (1982b) Effect of the insecticide cartap hydrochloride on soil microflora. *J. Pest. Sci.* 7: 1–7.

Summary: The effect of cartap hydrochloride (cartap-HCI; Padan) on soil microflora was examined under laboratory conditions. Cartap-HCI at 10 ppm (a normal application) and 100 pm treatments had no appreciable influence on the populations of fungi, actinomycetes, aerobic and anaerobic bacteria under upland and flooded conditions. However, the populations of the microorganisms were decreased by treatment at 1,000 ppm of the chemical under both conditions. Fungal and actinomycete populations were less in soil treated at 1,000 ppm than in untreated soil during sixty days. The numbers of aerobic and anaerobic bacteria at 1,000 ppm of the chemical under both conditions decreased for the first three and fifteen days, respectively, but subsequently recovered. Fungal flora was not affected by 10 and 100 ppm treatments under either condition, but the fungal composition was changed by 1,000 ppm treatment under upland conditions, namely, the rate of *Penicillium* sp. in total fungi decreased, while those of *Trichoderma* sp. and *Fusarium* sp. increased. Under flooded conditions, even treatment at 1,000 ppm made little or no remarkable change on the fungal flora.

Notes: Under flooded conditions, at recommended dose of 10 ppm and at 100 ppm had no effect on fungi, actinomycetes, aerobic bacteria, and anaerobic bacteria.

Fox, J.L. (1983) Soil microbes pose problems for pesticides. *Science* 221: 1029–1031. (NS)

Notes: Short review on the problem of pesticide inactivation by adaptive soil microflora.

Furusaka, C. (1978) Dynamic aspects of bacterial flora in connection with behaviors of pentachlorophenol scattered on paddy field—under consideration of methodology. *J. Pest. Sci.* (*Japan*) 3: 499–509. (In Japanese)

Summary: By citing an example of PCP applied in the paddy field, problems were discussed in relation to methodology applicable to the research on the transition of microflorae in the environment. The further problem seems to be how to generalize findings of the studies made both from micro and macroscopic viewpoint into a universal law.

Goring, C.A.I., Laskowski, D.A. (1982) The effects of pesticides on nitrogen transformations in soils. Pages 689–720 in *Nitrogen in agricultural soils*, American Society of Agronomy Madison, Wis., USA. (NS)

Notes: A review with tabulated data on pesticide effects on organisms and activity. Most of the information is on upland soils. 165 references including five references on ricefields.

Gowda, T.K.S., Rao, V.R., Sethunathan, N. (1977) Heterotrophic nitrification in the simulated oxidized zone of a flooded soil amended with benomyl. *Soil Sci.* 123(3): 171–175.

Summary: In a study of benomyl-soil microflora interactions in a simulated oxidized zone of a flooded soil, application of 5,000 ppm benomyl together with ammonium sulphate increased bacterial numbers in an alluvial soil. Nitrite was produced from ammonium in benomyl-amended soil, though in small quantities which disappears later. Oxidation of nitrite to nitrate was not evident. No nitrite was detected in unamended soil. Also, the predominant bacterium isolated from benomyl-amended soil and identified as *Pseudomonas* sp., oxidized ammonium to nitrite in a medium containing glucose. Moreover, oxidation of ammonium to nitrite occurred in benomyl-amended soil as well as in bacterial cultures even in the presence of N-Serve or AM at concentrations known to inhibit autotrophic nitrification. At the same time, benomyl, even at 100 ppm inhibited nitrification by *Nitrosomonas* and *Nitrobacter.*

Notes: The benomyl concentration used in this experiment (5,000 ppm) is much higher than the recommended dose (less than 1 kg ai/ha).

Greaves, M.P., Cooper, S.L., Davies, H.A., Marsh, J.A.P., Wingfield, G. (1978) *Methods of analysis for determining the effects of herbicides on soil micro-organisms and their activities.* Technical Report No. 45. Agricultural Research Council Weed Research Organization, Bagbroke Hill, Yarnton, Oxford, OX5 1PF, UK. 56pp. (NS)

Notes: Soil sampling, calculations to quantify pesticide use and most classical methods of soil microbiology are listed and described.

Ishizawa, S., Matsuguchi, T. (1966) Effects of pesticides and herbicides upon microorganisms in soil and water under waterlogged condition. *Bull. Nat. Inst. Agr. Sci. Ser. B* 16: 1–90. (NC)

Jayachandran, and Chandramohan, N. (1977) Influence of insecticides on the phyllosphere and rhizosphere of rice crop. *Riso* 26(4): 323–330.

Summary: Although all the insecticides tested were inhibitory to the phyllosphere microflora, contact insecticides exerted least inhibitory effect compared to systemic insecticide both on the twenty-fifth and fifty-fifth day of sampling. The insecticides applied to the rice plants altered the composition of the leaf exudates and there existed no relation between the leachate composition and phyllosphere microflora. On the twenty-fifth day although all the insecticides excepting counter and cytrolane stimulated the rhizosphere microflora, on the fifty-fifth day the contact insecticides alone were stimulatory. No correlation could be observed between the rhizosphere population and enzyme activity both on the twenty-fifth and fifty-fifth day of sampling.

Jena, P.K., Rajaramamohan Rao, V. (1987) Nitrogen fixation as influenced by pesticides and rice straw in paddy soils. *J. Agric. Sci. (G.B.)* 108(3): 635–638.

Summary: The effect of three herbicides and an insecticide combination on nitrogen fixation in three paddy soils was investigated in a laboratory incubation study. The influence of pesticide combination on N_2 fixation was evaluated in the presence and absence of rice straw under flooded and non-flooded conditions. In a non-flooded alluvial soil single or combined application of butachlor and carbofuran significantly stimulated N_2 fixation. There was no effect on N_2 fixation when thiobencarb was applied alone; but with thiobencarb in combination with carbofuran higher N_2 fixation occurred. Both oxadiazone and thiobencarb had no effect on N_2 fixation under flooded conditions, but in combination with carbofuran and N_2 fixation was high. In acid sulphate saline Pokkali soil, rice straw application stimulated N_2 fixation; the stimulatory effect of carbofuran either alone or in combination became more pronounced under flooded conditions. N_2 fixation was low in a laterite Sukinda soil and the effect of pesticides was not changed by rice straw amendment. A uniform stimulation of N_2 fixation occurred in soils when carbofuran was applied either singly or in combination with other herbicides tested. Results indicate that the effect of pesticides on N_2 fixation varied with the rice straw application and water regime.

Kai, H., Kamata, M., Kawagushi, S., Kanayama, H. (1986) Effects of herbicide applications on microbial ecosystem and fertility of paddy soil. I. Seasonal changes of microflora affected by repeated applications of herbicides in paddy soil. *Jap. J. Soil Sci. Plant Nutr.* 57(6): 535–543. (In Japanese) (NS)

Kandasamy, D., Marimuthu, T., Rajukkannu, K., Raghuraj, R., Oblisami, G., Krishnamoorty, K.K., Subrahmaniam, T.R. (1975) A study on the relationship between the dissipation of insecticides and rhizosphere microflora of paddy. *Madras Agric. J.* 62(4): 203–207.

Summary: A study on the interrelationship between the dissipation of two granular insecticides and different microbial populations in the rhizosphere soil of paddy crop indicated a positive correlation between the residues of phorate and actinomycete and *Azotobacter* populations. However, no such definite relationship could be recorded with carbofuran and various groups of microflora.

Kuthubutheen, A.J. (1980) Effect of pesticides on leaf and seed surface fungi of rice. Pages 1,021–1,028 in Furtado, J.I. (ed.) Tropical Ecology and Development. Proceedings of the fifth International Symposium of Tropical Ecology. April 16–21, 1979 Kuala Lumpur, Malaysia. The International Society of Tropical Ecology. 1383 pp.

Notes: Leaf and seed surface fungi of rice were monitored following the application of three fungicides and two insecticides. All pesticides reduced the number of leaf and seed fungi. Following the application there was a increased incidence of both numbers and species of *Curvularia.*

Lal, R., Lal, S. (eds.) (1988) *Pesticides and nitrogen cycle* vols. (1–3). CRC Press, Boca Raton, Fla., USA.

Notes: Topics covered include: Nature and habitats of microbes of N cycle. Experimental, methodological and analytical approach to study the effects of pesticides on N cycle. Effects on ammonification, nitrification, denitrification. Pesticides and N transformations in flooded soils. Effects on asymbiotic nitrogen fixation. Effects on Rhizobium-Legume symbiosis. Effects on blue-green algae.

Mahapatra, R.N., Rajaramamohan Rao, V. (1981) Influence of hexacyclohexane on the nitrogenase activity of rice rhizosphere soil. *Plant Soil* 59(3): 473–478.

Summary: The influence of application of BHC to a submerged tropical field soil, at rates equivalent to recommended field rates (1–2.5 kg ai/ha) and twice this level, upon the rhizosphere soil nitrogenase, N_2 fixers, and soil redox potential (Eh) was investigated. The rhizosphere soil from BHC-treated fields exhibited significantly higher nitrogenase activity than that from untreated fields. BCH retarded the drop in redox potential of the field soil up to eighty days after transplantation under submerged conditions. Populations of N_2-fixing *Azospirillum* sp. and *Azotobacter* to a greater extent and anaerobic organisms to a lesser extent, were stimulated in BCH-treated soils. Results indicate the stimulation of heterotrophic N_2-fixing bacteria by BCH in submerged paddy soils.

Mandal, B.B., Bandyopadhyay, P., Bandyopadhyay, S., Maity, S.K. (1987) Effect of some preemergence herbicides on soil microflora in direct seeded rice. *Indian Agric.* 31(1): 19–23. (NS)

Notes: Field experiment with microflora enumeration four, eleven, eighteen, and twenty-five days after application.

Mani, A., Prasad, N.N. (1978) Studies on the effect of phorate and disyston on nitrification in paddy soils. *Pesticides* 12(9): 33–34. (NC)

Marimuthu, T., Kandasamy, D., Oblisami, G., Subramaniam, T.R. (1975) Influence of foliar spray of certain pesticides on the phyllosphere microflora of paddy. *Sci. and Culture* 41(10): 490–492. (NS)

Mikkelsen, D.S. (1965) Use of chlorinated phenols as nitrification inhibitors in rice fertilization. *Rice J.* 68: 74. (NS)

Mitsui, S., Watanabe, I., Honda, S. (1962) Effect of pesticides on denitrification in paddy soil. I. *Jpn. J. Soc. Soil. Sci. Fert.* 33: 469–474.

Notes: Quoted in Azad and Khan (1968) Vapam depressed denitrification by about 40 percent when used at 20 ppm, whereas Dithane, BHC, and PCP caused less inhibition.

Mitsui, S., Watanabe, I., Honma, M., Honda, S. (1964) The effect of pesticides on the denitrification in paddy soil. *Soil Sci. Plant Nutr.* 10(3): 107–115.

Summary: Pot and laboratory experiments were conducted with the aim of examining the effect of pesticides and some other compounds on the denitrification in paddy soil. Konosu (Saitama Pref.) well drained alluvial paddy soil was used. Pot experiments revealed that Vapam and Dithane (Zineb) depressed the nitrification of urea dressed in soils under upland conditions. However, none of the pesticides examined (Vapam, Dithane, PCP, BHC) exerted a depressive effect on the denitrification of nitrate dressed under water-logged conditions. Vapam showed a remarkable promotion of the mineralization of soil nitrogen. After preincubation of air dried Konosu soil under anaerobic water-logged conditions in the laboratory, the added nitrate was rapidly disappeared, resulting in an approximately stoichiometric accumulation of gaseous products. The process of denitrification was measured by way of nitrate disappearance, nitrite accumulation, and evolution of gas other than CO_2 and O_2. Among dithiocarbamate compounds, Vapam (20 ppm) remarkably inhibited the denitrification, namely, depressed the denitrification approximately by four tenths. At 100 ppm, dithiocarbamates compounds besides Vapam depressed the nitrate disappearance according to the following: Ziram < Dithane < Thiuram < Ferban < Maneb < Nabam. Diethyl dithiocarbamate did not show any depressive action on denitrification. Nabam and Maneb, both alkyldiamine dithiocarbamate compounds remarkably depressed the denitrification. Zinc salt of ethylene-bis-dithiocarbamate (Dithane) depressed the denitrification slightly more than dimethyl dithiocarbamate (Ziram). Respiratory inhibitors such as azide and monoiodoacetate showed remarkable depression of denitrification. N-Serve (2-chloro, 6-(trichloromethyl) pyridine) at 14 ppm revealed slight inhibition (about 30 percent) of denitrification. The action of PCP (50 ppm), BHC (40 ppm), sodium chlorate (100 ppm) were much less inhibitive. Dicyandiamide at 50 ppm was not inhibitive. The inhibition of nitrate disappearance was similarly reflected on the inhibition of gas evolution from nitrate. Nitrite was accumulated in proportion to the suppression of nitrate reduction except for azide and N-Serve, that is nitrite reduction is more sensitive to pesticides than nitrate reduction. From the results described in this paper, it is concluded that soil denitrification is not so sensitive to pesticides as is nitrification.

Notes: Most of the chemicals are used at a concentration higher than that used in the fields.

Nair, K.S., Ramakrishnan, C., Sithanantham, S. (1973) Effect of soil application of insecticides on the nutrient status, bacterial population and yield in rice soils. *Madras Agric. J.* 60(7): 441–443.

Summary: Two field experiments were conducted during 1967–68 at the Agricultural College and Research Institute, Coimbatore, to find out the effect of soil application of sevidol, endrin and gamma BHC on the nutrient status and the bacterial population of the soil as observed at the time of harvest of the rice crop. At the dosages tried (0.45 to 2.25 kg ai/ha) none of three insecticides appeared to have any adverse effect on available N, P and K status of the soil. Also there could be observed no ill-effects on the bacterial population of the soil. Insecticidal application also resulted in significant increase in grain yields, the maximum increase being with sevidol, followed by endrin and gamma BHC.

Nair, K.S., Ramakrishnan, C., Sithanantham, S. (1974) Effect of soil application of insecticides of the nutrient status, bacterial population and yield in rice soils. *Indian J. Agric. Chem.* 7(1): 15–24.

Summary: Soil application of insecticides like sevidol, endrin and gamma BHC, are recommended for the control of rice stem borers. The present study consisted of two field experiments conducted during 1967–1968 at the Agricultural College and Research Institute, Coimbatore, to find out the effect of application of these insecticides on the nutrient status and the bacterial population of the soil as observed at the time of harvest of the rice crop. At the dosages tried (0.45 to 2.25 kg/ha) none of the three insecticides appeared to have any adverse effect on N, P and K status of the soil. Also there could be observed no ill-effects on the bacterial population of the soil. Insecticidal application also resulted in significant increase in grain yields, the maximum increase being with sevidol, followed by endrin and gamma BHC.

Nayak, D.N., Pasalu, I.C., Rajaramamohan Rao, V. (1980) Influence of natural and synthetic insecticides on nitrogen fixation (C_2H_2 reduction) in the rice rhizosphere. *Curr. Sci.* 49(3): 118–119. (NS)

Notes: The only paper comparing pesticides of plant origin with synthetic pesticides.

Nayak, D.N., Rajaramamohan Rao, V. (1980) Pesticides and heterotrophic nitrogen fixation in paddy soils. *Soil Biol. Biochem.* 12(1): 1–4.

Summary: The effect of three pesticides, benomyl, carbofuran and gamma-BHC at 5 ppm, rates equivalent to recommended field levels, on the heterotrophic N_2 fixation in five air-dried, cellulose-amended, submerged, tropical soils was investigated employing ^{15}N tracer technique under laboratory conditions. Addition of benomyl, a carbamate fungicide, to alluvial, laterite and two acid sulphate soils resulted in significant increases in N_2 fixation, while carbofuran, a methylcarbamate insecticide, exerted a stimulatory effect on N_2 fixation in alluvial, laterite and acid saline soils. Gamma-BHC, a chlorinated hydrocarbon insecticide, stimulated N_2 fixation in alluvial and acid sulphate pokkali soils, while considerable inhibition of N_2 fixation was evident in other soils. Results showed differential responses of specific groups of N_2-fixing organisms to the pesticides depending on the soil type.

Nayak, D.N., Rajaramamohan Rao, V. (1982) Pesticides and nitrogen fixation in a paddy soil. *Soil Biol. Biochem* 14(3): 207–210.

Summary: The influence of six pesticides, applied singly or in combination, on $^{15}N_2$ incorporation and C_2H_2 reduction in a submerged paddy soil was studied under laboratory conditions. While the application of diazinon had no marked effect, benomyl, carbofuran, parathion, nitrofen and -HCH, at concentrations close to recommended field application rates (5 g g-1) significantly stimulated N_2 fixation. Synergistic stimulatory effects of the pesticides on N_2 fixation were evident particularly in combinations of carbofuran with benomyl, nitrofen and -HCH. On the contray, diazinon slightly retarded the stimulatory effect of benomyl and carbofuran. Results indicated that the differential effects of pesticides on N_2 fixation could be attributed partly to fluctuations in the population of certain groups of N_2 fixers in submerged soil.

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benomyl and carbofuran. Results indicated that the differential effects of pesticides on N_2 fixation could be attributed partly to fluctuations in the population of certain groups of N_2 fixers in submerged soil.

Nishio, M. (1961) Some new soil-microbiological problems accompanying with recent changes of agricultural systems in Japan. *Bull. Inst. Agric. Res. Tohoku Univ. (Japan)* 36(1): 67–75.

Notes: Among several problems caused by crop intensification, the authors report an abnormal growth (dwarfing) of rice in fields treated with benthiocarb. This was found to be caused by a microbial metabolite: dechlorinated benthiocarb whose production is accelerated by straw application.

Nishio, M., Kusano, S. (1978) Effects of long-term application of organophosphate insecticides on bacterial numbers and nitrification in soil. *J. Cent. Agric. Exp. Stn.* 28: 39–48 (In Japanese). (NS)

Notes: Nitrification in soils having received insecticide for four consecutive years was not significantly different from the control. Data on total bacterial populations neither show clear differences between soils treated at the recommended dose and the control. On the other hand count of bacteria tolerant to organophosphate insecticides were two to four times higher in treated soils.

Pal, S.S. (1981) Interaction between pesticides and microbial activities in submerged soils. Ph. D. thesis, University of Calcutta, India. (NC)

Pal, S.S., Misra, A.K., Sethunathan, N. (1980) Inhibition of the reduction of flooded soils by hexachlorocyclohexane. *Soil Sci.* 129: 54–55.

Summary: In a study on the effect of hexachlorocyclohexane (HCH) on soil transformations in flooded soils, 5 percent granules of HCH were added to three soils to provide final concentrations of 5 to 100 parts per million of active ingredient, and the soils were flooded. Addition of HCH even at the 5-ppm level led to a remarkable decrease in formation of Fe^{2+} and, to a lesser extent, soluble manganese and prevented the drop in redox potentials in all soils. These effects of HCH were well pronounced also in the presence of added rice straw (0.5 percent), although rice straw alone hastened soil reduction. The inhibitory effect of HCH on soil reduction lasted even after 50 days of flooding.

Pal, S.S., Sudhakar-Barik, Sethunathan, N. (1979) Effects of benomyl on iron and manganese transformations in flooded soil. *J. Soil Sci.* 30: 155–159. (NS)

Palaniappan, S.P., Balasubramanian, A. (1985) Influence of two pesticides on certain soil enzymes. *Agric. Res. J. Kerala* 23(2): 189–192. (NS)

Notes: At recommended dose no marked effect on soil enzymatic activities but higher concentrations have often a negative impact.

Patnaik, N.C., Panda, N., Dash, P.C. (1986) Effects of 6 granular insecticides on rice rhizosphere microflora in India. *Int. Rice Res. Newsl.* 11(4): 30–31. (NS)

Notes: Even if differences in populations of microorganisms are significant they are most often not very marked.

Purushothaman, D., Venkataraman, C.V., Kasirajan, C. (1976) Attendant changes in the microflora of ricefield soil as influenced by the application of granular insecticides. *Madras Agric. J.* 63(8/10): 515–519.

Summary: The influence of six granular insecticides, viz. diazinon, cytrolane, carbofuran, carbaryl + lindane, quinalphos and Dursban on the quantitative changes in the microbial population of ricefield soils was studied. When applied at recommended doses (1.5 kg ai/ha) there was no deleterious effect on the fungal population due to the insecticides. Among the different insecticides, there was no significant difference in respect of their influence on the microbial population. The same inference held true with actinomycetes. However, the bacterial population underwent a significant fall due to the insecticidal application. When the activities of soil enzymes like phosphatase, ß-glucosidase and invertase were determined following the insecticidal application, ß-glucosidase alone was significantly inhibited and other enzymes recorded no change.

Raghu, K., MacRae, I.C. (1967a) The effect of gamma isomer of benzene hexachloride upon the microflora of submerged rice soils. I. Effect upon algae. *Can. J. Microbiol.* 13: 173–180. (NS)

Raghu, K., MacRae, I.C. (1967b) The effect of gamma isomer of benzene hexachloride upon the microflora of submerged rice soils. II. Effect upon nitrogen mineralization and fixation and selected bacteria. *Can. J. Microbiol.* 13: 621–627.

Summary: The effect of applications of benzene hexachloride (-BHC) to two submerged tropical soils at rates equivalent to recommended field practice (5 kg/ha) and 10 times this level upon the mineralization of native soil nitrogen was studied. No inhibitory effect on nitrogen mineralization was detected. A significant increase in the amount of nitrogen mineralized was detected in one of the soils over a period of 16 weeks of submergence. Additions of -BHC at 6 kg/ha

resulted in significant increases in nitrogen fixation in both soils. Populations of anaerobic, phosphate-dissolving bacteria were found to be higher in the two soils when they were treated with -BHC at 6 kg/ha.

Ramakrishna, C., Gowda, T.K.S., Sethunathan, N. (1979) Effect of benomyl and its hydrolysis products, AB and MBC on nitrification in flooded soil. *Bull. Environ. Contam. Toxicol.* 21: 328–333. (NS)

Ramakrishna, C., Rao, V.R., Sethunathan, N. (1978) Nitrification in simulated oxidized surface of flooded soil amended with carbofuran. *Soil Biol. Biochem.* 10: 555–556. (NS)

Ramakrishna, C., Sethunathan, N. (1982) Stimulation of autotrophic ammonium oxidation in rice rhizosphere soil by the insecticide carbofuran. *Appl. Environ. Microbiol.* 44(1): 1–4.

Summary: The application of the insecticide carbofuran (technical or formulated) to rice rhizosphere soil suspensions at 10 and 100 ppm (µg/ml) of active ingredient distinctly stimulated the autotrophic oxidation of ammonium. Evidence suggested that *Nitrosomonas* sp. was enriched in the presence of carbofuran. Formulated carbofuran (Furadan 3G) exhibited by technical-grade (99.5 percent) carbofuran, a result which was attributed to the $CaCO_3$ present in the formulation.

Ramakrishna, C., Sethunathan, N. (1983) Inhibition of heterotrophic and autotrophic nitrification in bacterial cultures by carbaryl and 1-naphthol. *J. Appl. Bacteriol.* 54: 191–195.

Summary: A carbamate insecticide, carbaryl, and its hydrolysis product, 1-naphthol, inhibited nitrification by a heterotrophic bacterium, a *Pseudomonas* sp., at a concentration of 50 g/ml and by chemoautotrophic bacteria, a *Nitrosomonas* sp. and a Nitrobacter sp., at a concentration of 10 g/ml, in pure cultures.

Rao, J.L.N., Pasalu, I.C., Rajaramamohan Rao, V. (1983) Nitrogen fixation (C_2H_2 reduction) in the rice rhizosphere soil as influenced by pesticides and method of their application. *J. Agric. Sci., Camb. (G.B.)* 110(3): 637–642.

Summary: The effect of pesticides on nitrogenase activity in rhizosphere soil from ricefields was investigated. The differential response of insecticides on nitrogenase depended on the method of field application. Results also showed that the differential response to the pesticides of specific groups of N_2-fixing microorganisms depended upon the method of application. Soil incorporation of

carbofuran stimulated the rhizosphere nitrogenase, while endosulfan and hexaclorocyclohexane inhibited it. Carbofuran and hexachlorocyclohexane stimulated nitrogenase when applied to the standing water. Seedling root dips of isofenphos stimulated nitrogenase, while endosulfan, BPMC and carbaryl showed a variable effect. Quinalphos inhibited nitrogenase irrespective of method of application.

Rao, J.L.N., Prasad, J.S., Rajaramamohan Rao, V. (1984) Nitrogen fixation (C_2H_2 reduction) in the rice rhizosphere soil as influenced by pesticides and fertilizer nitrogen. *Curr. Sci.* 53(21): 1155–1157. (NS)

Ray, R.C. (1981) Microbial activities in the rhizosphere of rice plants as influenced by pesticide applications. Ph.D. thesis, Utkal University, Bhubaneswar. (NC)

Ray, R.C., Ramakrishna, C., Sethunathan, N. (1980) Nitrification inhibition in a flooded soil by hexachlorocyclohexane and carbofuran. *Plant Soil* 56: 165–168.

Summary: The effect of a commercial granular formulation of hexachlorocyclohexane (HCH) on nitrification in a flooded soil was studied at 10 and 100 ppm ai. The oxidation of the added ammonium to nitrate was inhibited significantly at 10 ppm and almost completely at 100 ppm, concomitant with a proportional decrease in the populations of ammonium- and nitrite-oxidizing autotrophic bacteria. Of special interest is the synergistic increase in the inhibition of nitrification by a combined application of HCH and carbofuran.

Ray, R.C., Sethunathan, N. (1980) Effect of commercial formulation of hexachlorocyclohexane and benomyl in the oxidation of elemental sulfur in soils. *Soil Biol. Biochem.* 12: 451–453. (NS)

Ray, R.C., Sethunathan, N. (1988) Pesticides and nitrogen transformations in flooded soils. Pages 119–142 in R., Lal, Lal S. (eds.), *Pesticides and nitrogen cycle* (vol. 2.). CRC Press, Boca Raton, Fla., USA.

Summary: It is clear from the above survey that reports on the side effects of pesticides on microorganisms and their activities in flooded soils are not consistent. Conflicting reports of the same pesticide exhibiting innocuous, inhibitory, and stimulatory effects on a specific microorganism and its activity are not uncommon in literature. Because, methodology used in many of these studied is not uniform especially with regard to the concentration of the pesticide, formulation of the pesticide, the incubation conditions, sampling procedure, analytical techniques, and criteria used in evaluation of the side effects. In studies with formulations, a question arises whether the observed effects are due to the active ingredient, carrier in the formulation or synergistic interaction between the carrier and formulation. There are reports of synergistic interactions between a pesticide and carrier in the formulation, increasing the toxicity to insects. Evidently, for a meaningful conclusion, there is a need to generate data on the side effects from simultaneous studies with formulated and technical or analytically pure pesticide. Again, for chemically and/or biologically unstable pesticides such as carbamate and organophosphorus groups, the observed side effects after application of parent molecule may be due to their breakdown products and not necessarily due to the parent molecule. 1-Naphthol, hydrolysis product of carbaryl, is more toxic than carbaryl to certain microorganisms and their activities. Unfortunately in the experimental design and in the interpretation of results, the role of breakdown products of specially unstable insecticides is often neglected. In majority of studies on the side effects of pesticides, data were generated under laboratory conditions using relatively high concentration of pesticides. Extrapolation of these results to actual field conditions is therefore questionable. Pure culture studies may not have much relevance since in nature a vast range of microorganisms interact with each other and the net effect on microbial community is more important than the effect on individual microorganisms. This is particularly true in transformations such as denitrification and nitrogen fixation, which are carried out by a myriad of taxonomically different microorganism. Despite the inconsistency and several differences in the reported studies, certain definite conclusions are possible. Contrary to the common belief that pesticides applied at recommended levels and intervals seldom affect, adversely or beneficially, the microbial processes, certain pesticides such as carbofuran even when applied to the soil at recommended level effected striking stimulation of nitrogen fixation and autotrophic oxidation of ammonium. Likewise, there is convincing evidence in support of significant interactions between pesticides in a combination, as for instance carbofuran and HCH applied at individually subtoxic levels leading to increased toxicity to nitrification. There is an urgent need to demonstrate these and other side effects of pesticides in a more complete model ecosystems comprising various biotic and abiotic components of a flooded ricefield. Such microcosm studies would help in a better understanding of the significance of the interactions of the pesticide with the microbial community in the nutrient-rich rhozosphere soil and overall impact of such interactions on soil fertility.

Roy, P., Sinha, P.K., Mukherjee, N. (1975) Effect of granular insecticides on rice soil microflora. *Indian J. Entomol.* 37(1): 93–95. (NS)

Notes: Inhibitory effects of diazinon, carbofuran, and endosulfan at recommended dose were observed on microbial populations at 3 and 9 DAA but they recovered at 20 DAA. Diazinon had a promoting effect on fungal populations.

Russo, S. (1970) Effects of some pesticides on the solubility of nutrients in submerged soil. *Riso* 19(1): 37–54.

Summary: An experiment has been carried out to study the influence of some chemical used as pesticides, namely potassium azyde, Ordram, and A-40 Dithane, on the availability of nutrients in flooded soil. The chemicals have been confronted with a untreated test at the following doses: Potassium azyde, 4, 6, and 10 kg/ha; Ordram, 55, 65, and 80 kg/ha; Dithane A-40, 8, 10, and 15 kg/ha. For every treatment three replications were carried out in pots, containing soil carefully mixed with the chemical, and submerged with daily addition of water to compensate the evaporation. Every 20 days, and for a total period of 80 days, a soil sample was analyzed for NH_4 exchangeable, soluble P_2O_5, soluble K_2O, and organic matter. The effect of Dithane A-40 on the NH_4 availability has been superior to that of potassium azyde. The action of Ordram, on the contrary, has been negative. The P availability has been increased, both with K azyde and with Ordram, whereas the positive effect of Dithane has been observed only with the lowest doses. At all levels, the three pesticides has favored the solubility of K. The decomposition of organic matter has been loosened by all the chemical. However, the algal development may have interfered with the process. It is suggested that effects observed on the solubility of nutrients is possibly correlated with phenomena of stimulation and inhibition of the soil microorganisms. The P availability, on the other hand, may have been affected also by the capacities of the active chemical groups of the pesticides to substitute for P ions, freed from stable combinations of the soil constituents.

Russo, S. (1971) Effects of insecticides on the biological factors in submerged ricefields. *Riso* 20(4): 331–349.

Summary: The effects of insecticides on the soil are examined in the present paper. Particular attention is given to the balance of the microbial population, to the biochemical processes affecting the mobility of nutrients, to the enzymatic activity of the soil. Studies carried out until now emphasize the necessity to maintain the biological balance of the soil in order to safeguard the normal biochemical processes affecting the fertility. The results of researches about the behavior of insecticides in submerged soils are discussed. It has already been ascertained that the degradation of some insecticides is faster in flooded fields than under normal agronomic conditions. Furthermore, it seems that insecticides may affect the biochemical anaerobic processes, determining changes in the mobility of the nutrients.

Sahrawat, K.L. (1975) Effects of pesticides on nitrogen fixation. *Pesticides* 9: 21–23. (NC)

Sandhu, K.S., Randhawa, K.S., Chahal, V.P.S. (1978) The effect of some herbicides on the rhizosphere microflora in the seed crop of okra *Abelmoschus esculentus* (L.) Moench. *Indian J. Ecol.* 5(1): 61–66.

Summary: The bacterial population was higher in three controls, i.e., control weeded, unweeded and handpulling, than that in all herbicidal treatments. Alachlor at 1.94 kg ai/ha resulted in a significant increase in the actinomycetes population, whereas alachlor at 2.50 kg ai/ha, EPTC [S-ethyl N, N-dipropyl thiolcarbamate] + alachlor at 3.75 + 1.25 kg ai/ha, respectively, and fluchloralin at 1.20 and 0.90 kg ai/ha were on a par with the controls, handpulling and unweeded. The fungal population was relatively unaffected by the various herbicidal treatments, except nitrofen + linuron at 1.25 + 0.25 kg ai/ha, EPTC at 0.75 kg ai/ha, dichlormate at 5.00 kg ai/ha, EPTC + nitrofen at 3.75 + 0.62 kg ai/ha, and nitrofen at 1.25 kg ai/ha which caused a significant reduction in the fungal population as compared with that in the controls.

Sathasivan, K., Palaniappan, S.P., Balasubramaniyan, P. (1982) Effect of insecticide application on nitrogen transformation in flooded soil. *Int. Rice Res. Newsl.* 7(1): 19. (NS)

Sato, K. (1985) Effect of pesticide on soil microorganisms. *Shokucho* 19(6): 2–17 (In Japanese). (NS)

Sato, K. (1986) Effect of pesticide on soil microorganism with special reference to herbicide and microflora. *Shokucho* 20(1): 3–19 (In Japanese). (NS)

Sato, K. (1987) Seasonal population changes of several bacterial groups in paddy soil in relation to application of a herbicide, benthiocarb. *Bull. Inst. Agric. Res. Tohoku Univ.* 38(2): 69–82.

Summary: Population changes of several bacterial groups were surveyed in relation to the application of a herbicide, benthiocarb (S-chlorobenzyl diethylthiocardamate). Changes in the amount of NH_4-N and dissipation of benthiocarb were also followed: (1) counts of total viable bacteria and Gram-negative

bacteria gradually increased after water-logging. The increase was followed by a gradual decrease after the flowering period of rice plant. This trend of changes in the counts was very similar to that observed previously in the paddy field soil. Benthiocarb application enhanced the initial increase in both the counts, but it did not affect the counts thereafter; (2) counts of ammonifying, nitrate-reducing and denitrifying bacteria changed irregularly during the surveying period as observed previously. Benthiocarb application increased the initial increase in the counts of all of the bacterial groups as well; (3) the numbers of ammonium-oxidizing bacteria and nitrite-oxidizing bacteria increased at the initial period after water-logging. However, benthiocarb inhibited the initial increase in accordance with the amounts of benthiocarb. After the inhibition of the initial increase by the herbicide the numbers changed similarly in all the plots regardless of the application of the herbicide; (4) drainage of the plots of the paddy field where the dwarfing of rice plants occurred did not affect the pattern of the population changes of several bacterial groups except nitrifying bacteria whose numbers slightly increased after drainage; (5) the amount of ammonium-N decreased after water-logging, and its initial decrease was conspicuous in the plots applied with ten times of recommended rate (10 r. r.) of benthiocarb. Drainage decreased the amount of ammonium-N as well; (6) benthiocarb dissipated after water-logging and its decrease was remarkable in July when temperature was elevated. Dechlorinated benthiocarb was accumulated in the plots applied with 10 r. r. of the herbicide, but was not detected in the plots applied with recommended rate (r. r.) of the herbicide in site of dissipation of the compound; (7) there was a marked difference in the values of yield components of rice plant between the two groups of plots; one applied with 10 r. r. and the other with r. r. of benthiocarb. The yield components were very similar between the plots with r. r. of benthiocarb and without the compound. These phenomena corresponded very well to the dwarfing which can be caused by the accumulation of dechlorobenthiocarb.

Sethunathan, N., Macrae, I.C. (1969) Some effects of diazinon on the microflora of submerged soils. *Plant Soil* 30(1): 109–112.

Summary: The application of diazinon, an organophosphorus insecticide, at the rate of 2 kg and 20 kg active ingredient per hectare to submerged Maahas clay significantly stimulated the actinomycete population. A distinct zone of brown pigmentation formed in that part of the profile commonly referred to as the oxidized layer. A profuse growth of actinomycetes developed from the soil samples of this pigmented zone when streaked onto the nutrient agar. A visible increase in algal populations was noted in the standing water of the diazinon-treated soil.

Sethunathan, N., Pathak, M.D. (1971) Development of a diazinon-degrading bacterium in paddy water after repeated applications of diazinon. *Can. J. Microbiol.* 17: 699–702.

Summary: A decline in the brown planthopper control effectivity of diazinon was noticed after its continuous application to rice paddies for three one-half years at the International Rice Research Institute. In a study undertaken to determine the factor involved in this decline, rapid inactivation of diazinon was recorded within three to five days of its incubation with water from a ricefield that had received several applications of diazinon. During the same period, its degradation in water from an untreated ricefield was non-significant. This indicated the development of a degrading agent in paddy water following diazinon treatments. The inactivation of diazinon on incubation with water from treated fields was retarded if the incubation mixture was sterilized or kept anaerobically. Release of $^{14}CO_2$ from ^{14}C-diazinon was rapid from water of treated fields, but was inhibited when streptomycin was added to the system. A lag of two or three days, followed by a rapid degradation, was generally evident. Thus these data established the fact that aerobic biological agents, capable of degrading diazinon in paddy water, develop after diazinon application. A bacterium, *Arthrobacter* sp., capable of metabolizing diazinon in the presence of ethyl alcohol or glucose was isolated from paddy water of treated fields.

Sethunathan, N., Siddaramappa, R., Siddarame Gowda, T.K., Rajaram, K.P., Barik, S., Rao, V.R. (1976) Pesticide-soil microflora interactions in flooded rice soils. Pages 27–36 in *Trace contaminants of agriculture, fisheries and food in developing countries.* Vienna: International Atomic Energy Agency (IAEA).

Summary: Isotope studies revealed that gamma and beta isomers of HCH (hexachlorocyclohexane) decomposed rapidly in nonsterile soils capable of attaining redox potentials of -40 to -100 mV within 20 days after flooding. Degradation was slow, however, in soils low in organic matter and in soils with extremely low pH and positive potentials, even after several weeks of flooding. Under flooded conditions, endrin decomposed to six metabolites in most soils. There is evidence that biological hydrolysis of parathion is more widespread than hitherto believed, particularly under flooded soils conditions. Applications of benomyl (fungicide) to a simulated-oxidized zone of flooded soils favoured heterotrophic nitrification.

Setter, T.L., Waters, I. (1987) *Guide for environmental measurements on rice.* School of Agriculture, University of Western Australia, Nedlads, Western Australia. 6009. 32pp. (NS)

Notes: A compilation of classical methods for biological measurements in ricefields which might be used for assessing pesticide impacts.

Sidorenko, O.D., Klyuchareva, N.N., Nitse, L.K. (1986) Nitrogen-fixing activity of soil samples in ricefields after application of herbicides and straw. *Izv. Timiryasev S-KH. Akad.* 5: 188–191 (in Russian). (NS)

Simon-Sylveste, G., Fournier, J.C. (1979) Effects of pesticides on the soil microflora. *Adv. Agron.* 31: 1–92. (NS)

Notes: A review dealing mostly with upland soils. More than 500 refs are listed.

Singh, R.P., Rana, R.S., Carg, G.K. (1986) Effect of sevidol on nitrification under submerged conditions. *Pesticides* 20(2): 52–54.

Summary: In view of the importance of nitrogen cycle, the present study was carried out to see the effect of sevidol on nitrifying bacteria in simulated water logged soil under laboratory conditions. Sevidol at higher concentration (2 kg ai/ha) stimulated the NO_2-N formation without affecting the NO_3-N level in the soil. However, sevidol at lower (0.5 kg ai/ha) and field recommended concentration (1 kg ai/ha) did not affect the nitrification process in the soil.

Sivaraj, K., Venugopal, M.S. (1979) Influence of mephosfolan on the rhizosphere microflora of rice grown in different soil types. *Pesticides* (Nov.): 23–26.

Summary: Mephosfolan 0.75 and 1.0 kg ai/ha increased the bacterial population in Lower Bhavani soil while a decrease was recorded in Aduthurai and Coimbatore soils. In general, mephosfolan application increased the actinomycete population in Lower Bhavani and Coimbatore soils while a reduction was noted in Aduthurai soil. There was a reduction in the fungal population at all stages in Aduthurai and Coimbatore soil although variations were observed in Lower Bhavani soils while a general reduction was observed in Coimbatore soil.

Sivasithamparam, K. (1970) Some effects of an insecticide ("Dursban") and a weedicide ("Linurion") on the microflora of a submerged soil. *Riso* 19(4): 339–346.

Summary: Microbiological analyses of a submerged soil treated with an insecticide (Dursban) and a weedicide (Linuron) showed inhibition of the two groups of nitrifiers at the time of the first sampling (at 3 weeks), and a recovery in their numbers at the time of the second sampling (at 3 months). There was a general stimulation of aerobic bacteria, actinomycetes, ammonifiers, sulphate reducers,

cellulose decomposers and heterotrophic iron precipitators by both the chemicals at both time of sampling. Both treatments generally depressed denitrifiers. Anaerobic N fixers were stimulated by both the chemicals three weeks after treatment. Dursban showed a temporary inhibitory effect on aerobic P dissolvers, and a stimulation of anaerobic P dissolvers at the second sampling. The insecticide also markedly inhibited aerobic N fixer at the latter stage. Linuron showed stimulation of fungi at both samplings and aerobic N fixers at the second sampling. The weedicide appeared to have an inhibitory effect on anaerobic N fixers. The treatment with Dursban resulted in a visible increase in the algal population while the weedicide treatment resulted in a visible suppression of the organisms.

Somerville, H.J. (1978) Pesticides, microorganisms and the environment. *Span.* 21(1): 35–37. (NS)

Sudhakar-Barik, Ramakrishna, C., Sethunathan, N. (1979) A change in the degradation pathway of parathion after repeated application to flooded soil. *J. Agric. Food Chem.* 27: 1391–1392.

Summary: The degradation pathway of parathion shifted to hydrolysis from reduction after repeated applications of parathion or its hydrolysis product, p-nitrophenol, to a flooded soil. This shift occurred as a result of the proliferation of parathion-hydrolyzing microorganisms that utilized p-nitrophenol as the energy source. This is probably the first report of the enrichment of a population capable of degrading a parent molecule upon application of the primary product of its metabolism.

Swamiappan, M., Chandy, K.C. (1975) Effect of certain granular insecticides on the nodulation by nitrogen-fixing bacteria in cowpea (*Vigna sinensis L.*). *Curr. Sci.* 44(15): 558–559. (NS)

Takaku, T., Takahashi, M., Otsuki, A. (1979) Dispersion of an organophosphorus insecticide, fenitrothion in paddy fields and its effects on the microorganisms. *Jap. J. Limnol.* 40(3): 137–144 (In Japanese). (NS)

Tirol, A.C., Santiago, S.T., Watanabe, I. (1981) Effect of the insecticide carbofuran on microbial activities in flooded soil. *J. Pestic. Sci.* 6: 83–90.

Summary: The effects of carbofuran on some soil microbial activities—nitrogen mineralization, nitrification, N_2 fixation by blue-green algae, and urea hydrolysis—were investigated in the laboratory and the greenhouse. The addition of 10 g ai carbofuran per gram dried soil had no inhibitory effect on the

mineralization of native soil nitrogen. Nitrifying activity was enhanced in flooded soil treated with 10, 20, 50, and 100 ppm ai carbofuran. Nitrifying activity increased with increasing carbofuran concentration. The growth of blue-green algae was promoted by addition of 6 kg ai carbofuran/ha to the floodwater. Subsequently, a marked increased in the acetylene reduction activity of carbofuran-treated floodwater was obtained. Turbidity and an abundance of green algae distinguished the untreated floodwater from the carbofuran-treated one. The positive effect of carbofuran on phototrophic N_2-fixation appeared after its decomposition. The addition of up to 15 ppm ai (μg/ml floodwater) carbofuran had no effect on the acetylene-reduction activity of *Gloeotrichia* sp., but 20 ppm ai caused a significant lowering of that activity. The rate of urea hydrolysis appeared to be faster in dryland than in flooded soil. The addition of 50 ppm ai carbofuran did not affect the rate of urea hydrolysis.

Tu, C.M. (1978) Effect of pesticides on acetylene reduction and microorganisms in a sandy loam. *Soil Biol. Biochem.* 10(6): 451–456.

Summary: A study was made of the effects of thirty-two pesticides at two concentrations on nitrogenase activity (C_2H_2 reduction). N_2 fixers, bacteria and fungi in an agricultural sandy loam. Chlorfenvinphos, chlorpyrifos, carbofuran, metalkamate and permethrin at both rates, and ethoprop, leptophos and chlordane at the high rate depressed C_2H_2 reduction. The population of N_2 fixers was not suppressed significantly. Bacterial and fungal populations initially decreased with some pesticide treatments but recovered rapidly to levels similar to or higher than those in the controls.

Tu, C.M. (1979) Influence of pesticides on acetylene reduction and growth of microorganisms in an organic soil. *J. Environ. Sci. Health Part B Pestic. Food Contam. Agric. Wastes* 14(6): 617–624.

Summary: The effects of thirty-two pesticides at two concentrations on acetylene reduction (non-symbiotic nitrogen fixation), nitrogen fixers, bacteria and fungi in an organic soil were assessed. None of the pesticide treatments suppressed C_2H_2 reduction as compared to controls. No significant inhibition of the population of non-symbiotic nitrogen fixers occurred. However, stimulatory effects were observed with treatments of fensulfothion, fonofos, oxamyl, DDR, Telone R and Telone CR. Bacterial and fungal populations showed temporary declines but all recovered within 7 days to levels similar to or higher than those in the controls.

Tu, C.M., Miler, J.R.W. (1976) Interactions between insecticides and soil microbes. *Residue Rev.* 64: 17–65.

Summary: A survey has been made of the known inhibitory effects of insecticides on microorganisms. Some recent work on the degradation of insecticides is also included. Many of the various chemicals used as insecticides apparently have little effect on soil microorganisms under certain conditions. The toxicity of the chemicals may manifest itself in reduction of microbial growth rate, basic activity in metabolism and reproduction. Investigations so far, however, indicate that when insecticides are used at recommended field rates these chemicals will not significantly reduce indigenous microbial activities that are important in soil fertility, and in some cases they are stimulatory. Excessive applications may be temporarily depressive. Certain microbes may become adapted to the chemicals. In a less competitive environment, by utilizing the dead cells of the organisms killed by the insecticide, they reach very high numbers. The population of organisms capable of degrading insecticides, therefore, increases dramatically as a result of insecticide application. The extent of the degradation depends on numerous factors. All organisms, but particularly aquatic microorganisms, absorb and concentrate insecticides from their environment. Although several workers have demonstrated that soil microorganisms are able to degrade even the most stable and persistent organic insecticides, no one has yet demonstrated that these compounds serve as nutritional or energy sources for organisms leading to elimination of the compounds from the environment. Little is known about the metabolism of insecticides at any level. It appears that many microorganisms can metabolize the insecticides to some extent, but in some cases this limited metabolism leads to the production of even more toxic and persistent substances. Some organochlorine insecticides such as BHC, DDT, aldrin, heptachlor, dieldrin, toxaphene, and chlordane are highly resistant to degradation in soil and remain in the soil for long periods of time as residues. The addition of biodegradable organic material to the soil will enhance the growth of certain groups of microorganisms and influence insecticidal chemical reactions as a result of stimulated microbial activity and changes in soil aeration. Evidence shows that anaerobiosis of soil microorganisms stimulates the degradation of many insecticides. Exceptions are heptachlor epoxide and dieldrin, which are very persistent in both aerobic and anaerobic environments. Certain microorganisms possessing wide-spectrum enzymes might be able to degrade such insecticides. Organophosphorus and carbamate insecticides or their degradation products are readily metabolized by bacteria, actinomycetes, fungi, and algae in soil. To date, much of this work has been confined to laboratory studies and has yet to be translated into the development of more effective measures in the reduction of insecticidal residue in the field.

Turner, F.T., (1979) Soil nitrification retardation by rice pesticides. *Soil Sci. Soc. Am. J.* 43(5): 955–957.

Summary: The effectiveness of selected rice pesticides carbofuran, propanil, bifenox and sodium azide in comparison to nitrogen and terrazole in retarding soil nitrification was evaluated by determining increases in nitrate-N concentrations and/or decreases in ammonium-nitrogen concentrations. In a vertisol to which 50 ppm ammonium-N had been added and pesticide applied at recommended application rates, all compounds showed evidence of nitrification inhibition during the first 10 days of incubation. After 60 days incubation, only bifenox, sodium azide, terrazole, and nitrapyrin were still retarding nitrification. Similarly in another experiment the pesticides, applied at one-half to 10 times the recommended application rate, were not as effective as nitrapyrin and terrazole in retarding nitrification in a moist alfisol and vertisol; yet, each pesticide exhibited some nitrification inhibition, especially at the excessive application rate. The effectiveness of the individual pesticides in retarding nitrification varied with soil type. These rice pesticides have potential to retard nitrification that should be recognized when studying N transformations in soils or when studying the effect of pesticides on plants grown in soil.

Wainright, M. (1978) A review of the effects of pesticides on microbial activity in soils. *J. Soil Sci.* 29: 287–298.

Summary: The paper reviews the recently published literature (mainly since 1970) on the effects of pesticides on the major biogeochemical cycles in soils, including transformations of carbon, nitrogen, phosphorus sulphur, trace elements and soil enzymes. The main conclusion is that pesticides, with the exception of fumigants and some broad spectrum fungicides, have little deleterious influence on soil processes when applied at field rates. Obvious gaps in our knowledge of pesticide-soil interactions are pointed out and suggestions are made where future research is needed.

Wardle, D.A., Parkinson, D. (1990) Influence of the herbicide glyphosate on soil microbial community structure. *Plant Soil* 122(1): 29–38.

Summary: The side effect of glyphosate on the soil microflora were monitored by applying a range of glyphosate concentrations (0, 2, 20 and 200 μg/g herbicide) to incubated soil samples, and following changes in various microbial groups over twenty-seven days. Bacterial propagule numbers were temporarily enhanced by 20 μg/g and 200 μg/g glyphosate, while actinomycete and fungal propagule numbers were unaffected by glyphosate. The frequency of three fungal species on organic particles in soil was temporarily enhanced by 200 μg/g glyphosate, while one was inhibited. One species was temporarily enhanced on mineral particles. However, many of these fungi were inhibited by 200 μg/g glyphosate in pure culture. There was little agreement between species responses to glyphosate in incubated soil samples and in pure culture.

Watanab, I. (1978) Pentachlorophenol (PCP) decomposing activity of field soils treated annually with PCP. *Soil Biol. Biochem.* 10: 71–75.

Summary: Soil from field plots (Hokkaido Agricultural Experiment Station, Memuro, Japan) that had been treated once a year with pentachlorophenol (PCP) and from untreated plots was tested for PCP-decomposing activity in the laboratory. When PCP as an aqueous solution of pentachlorophenolate was added to both sets of soil samples, no significant difference was noticeable in the PCP-decomposing activity, despite a 1,000-fold difference in the number of PCP-decomposing microorganisms. When PCP was added as a PCP-celite mixture, however, PCP-decomposing activity was related to the history of the plot's treatment. The activity of the soil from PCP field plots was consistently higher than that from non-treated plots. When PCP was added to the untreated soil and incubated, the number of PCP-decomposing microorganisms increased, reaching the same order as that of PCP-treated soil plots after 3–4 weeks.