APPENDIX D

ANNOTATED BIBLIOGRAPHY ON THE EFFECTS OF PESTICIDES ON PHOTOTROPHIC MICROORGANISMS OF RICEFIELDS

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The first part of the compilation is annotated bibliography presenting 311 references dealing with the effects of pesticide on ricefield algae. Papers selected in this compilation include

- All papers dealing with studies of pesticides and algae conducted in ricefields, or with ricefield soil, or *in vitro* with strains isolated from ricefields;
- Considering the importance of blue-green algae for the N fertility of ricefields, all papers dealing with BGA and pesticides; and
- A limited number of papers of interest for methodological aspects or with data useful for comparison.

The second part presents summarized information on the effects of the pesticides tested on ricefield algae. This information is arranged according to pesticides. It also includes basic information on the pesticides tested.

Tabulated values of the recommended doses of pesticides tested are presented in the third part of the compilation.

This information is also available in two Hypercard stacks. The first stack (370 Kbytes) is a bibliographic database. Figure D.1 presents an example of a card on this stack. The second stack (130 Kbytes) compile information according

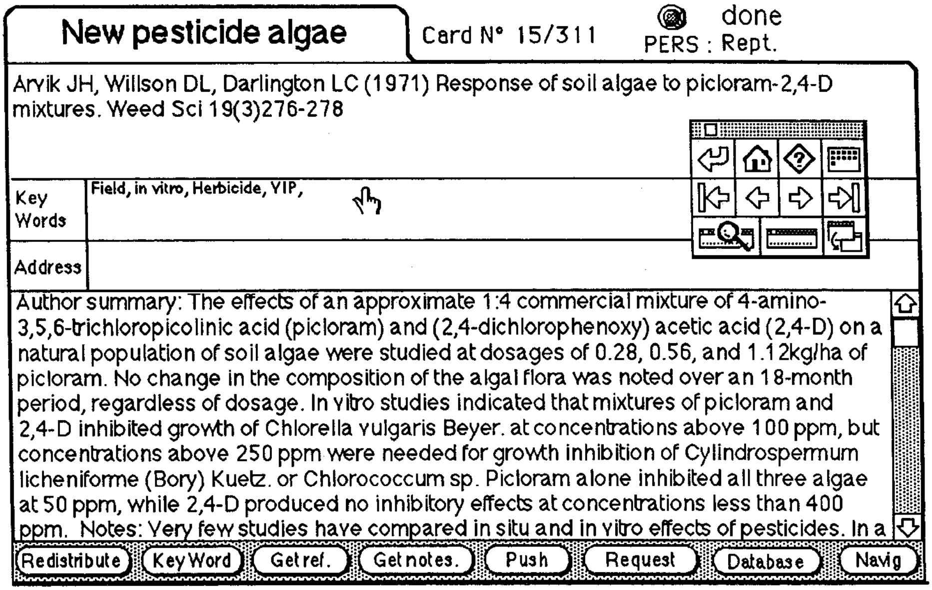

Figure D.1. Example of a Card of the Bibliographic Database on Hypercard

to pesticides and summarizes the recorded effects on a grid (Figure D.2). Both databases are linked and allow cross-reference.

Part 1. Bibliographic Compilation

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

Adamson, R.P., Sommerfield, M.R. (1980) Laboratory comparison of the effectiveness of several algicides on isolated swimming pool. *Appl. Environ. Microbiol.* 39(2): 348–353.

Summary: The most frequently encountered species of algae found in swimming pools in the Phoenix metropolitan area were used to evaluate the laboratory effectiveness of five commercially available pool chemicals used for algal control. The pool algae used were the xanthophyte *Pleurochloris pyrenoidosa*,

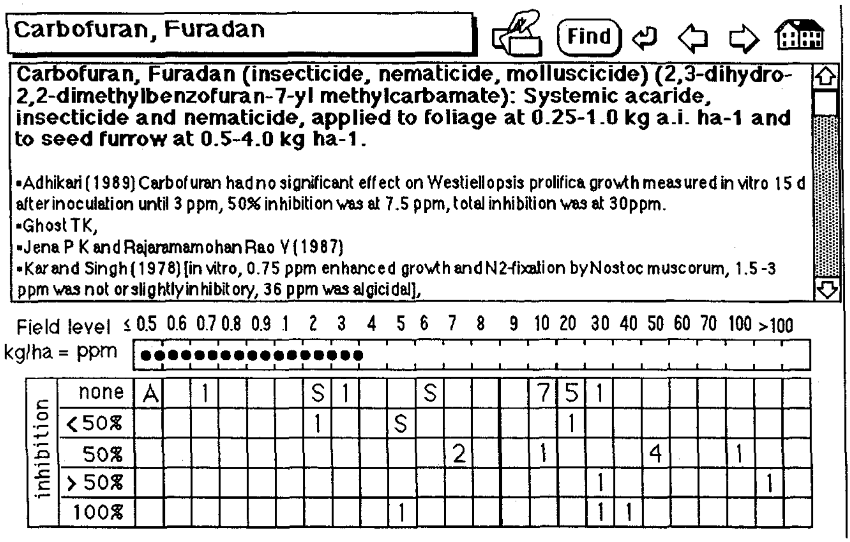

Figure D.2. Example of a Card of the Pesticide Database on Hypercard

the chlorophyte *Oocystis* sp., and the cyanophytes *Phormidium minnesotense* and *Plectonema* sp. Pad Algae Kill (a chlorine derivative) was effective in the control of all test organisms. Algaedyn, a silver-containing algicide, was effective on *P. minnesotense* and *Plectonema* sp., but caused only a slight inhibition in the growth of *P. pyrenoidosa* and *Oocystis* sp. Quarternary ammonium (Padicide) was more effective in controlling the growth of *Phormidium* and *Plectonema* than *Pleurochloris* and *Oocystis*. Algimycin (herbicide) only reduced the growth of *Oocystis* and was ineffective on the other species. Bio-Gard (copper) reduced the growth of *Pleurochloris*, but had no effect on the other test organisms. The technique used to quantify the influence of algicides on isolated pool algae appears to be adaptable to those algae that form distinct colonies on an agar substratum.

Notes: The quantities of a.i. of algicide used ranged from 0.02 to 2.4 ppm (Padicide: 0.36; Algimycin: 0.6; BioGard: 0.57; Algaedyn: 0.02; Pad Algae Kill: 2.4).

Addison, D.A., Bardsley, C.E. (1968) *Chlorella vulgaris* assay of the activity of soil herbicides. *Weed Sci.* 16: 427–429.

Summary: An assay technique utilizing *Chlorella vulgaris* Beijerinck gave highly significant responses to low concentrations of aqueous 3-(p-chlorophenyl)-1,1 dimethylurea (monuron), 3-(3,4-dichloronophenyl)-1, 1-dimethylurea (diuron),

and 2,4-bis (isopropylamino)-6-methylmercapto-s-triazine (prometryne) following 6 days of incubation. Water extracts of diuron from soil assayed with this organism were highly correlated with diuron added to the soil. Similar correlations for oats (*Avena sativa* L.) grown on the soil and for diuron in the water extracts as dichloroaniline serve to substantiate the relative effectiveness of the method. Assay of soil samples from field residue plots taken 150 days after herbicidal application showed that active residues of diuron and prometryne were detectable by the organism. Although the chemical method was faster, it has the disadvantage of measuring any dichloroaniline residues rather than only the active residues. The method developed insures a considerable saving in time over herbicide assays involving higher plants and gives reasonably good quantitative data on low concentrations of toxic monuron, diuron, and prometryne.

Adhikary, S.P. (1989) Effect of pesticides on the growth, photosynthetic oxygen evolution and nitrogen fixation of *Westiellopsis prolifica*. *J. Gen. Appl. Microbiol.* 35(4): 319–326.

Summary: We examined the effect of the pesticides Furadan (Carbofuran, 3 percent), Sevin (Carbaryl, 50 percent), Rogor (Dimetnoate, 30 percent EC) and (Endosulfan, 35 percent EC) on the survival, growth, photosynthetic oxygen evolution, and nitrogen fixation of the cyanobacterium *Westiellopsis prolifica*. Lower concentrations of the carbamate and organophosphate pesticides (10 ppm) increased the growth and nitrogen fixation while higher concentrations (> 20 ppm) had an inhibitory effect. The organochlorine pesticide Endotaf was toxic even at 10 ppm. Survivability and nitrogen fixation of cyanobacterium was reduced to 72 and 93 percent respectively in the presence of 100 ppm of Endotaf. An exposure of the filaments to over 100 ppm of Furadan, Sevin or Rogor caused about a 40 percent inhibition of the photosynthetic oxygen evolution. Endotaf was more toxic than the other pesticides. Oxygen evolution was totally suppressed after incubation of the organism with over 250 ppm of Endotaf; there was similar suppression of O_2 evolution on treatment with more than 500, 1,000, and 1,500 ppm of Rogor, Sevin and Furadan respectively.

Notes: Pesticide concentrations are apparently indicated in ppm of commercial formulation and not as active ingredient. Following data are expressed as ppm ai; Effect was estimated as dry weight measured *in vitro* fifteen days after inoculation. Carbofuran had no significant until 3 ppm, 50 percent inhibition was at 7.5 ppm, total inhibition was at 30 ppm. Sevin had no significant effect until 50 ppm, 50 percent inhibition was at 125 ppm, total inhibition was at 500 ppm. Rogor had no significant effect until 15 ppm, 50 percent inhibition was at

30 ppm, total inhibition was at 300 ppm. Endotaf had no significant effect until 6 ppm, 50 percent inhibition was at 15 ppm, total inhibition was at 300 ppm.

Adhikary, S.P., Pravata, Dash, Pattnaik, H. (1984) Effect of the carbamate insecticide, Sevin on *Anabaena* sp. and *Westiellopsis prolifica. Acta Microbiol. Hung.* 31(4): 335–338.

Summary: Effect of the insecticide Sevin [carbaryl]-1-naphthyl methyl carbamate (50 percent wt/vol) was examined on survival, growth and N_2 fixation of two soil-inhabiting, filamentous blue-green algae, *Anabaena* sp. and *W. prolifica.* Lower concentration of the insecticide (10 g/ml) increased survival, growth and N_2 fixation while higher concentrations showed an inhibitory effect.

Ahluwalia, A.S. (1988) Influence of saturn and knockweed on the growth and heterocyst formation in nitrogen-fixing blue-green alga. *Pesticides* (Bombay) 22(10): 43–44.

Summary: Saturn and knockweed inhibited the algal growth at relatively higher concentrations. Saturn was more toxic than the knockweed. Lethal doses for saturn and knockweed were recorded to be 20 ppm and 1000 ppm, respectively. There was no significant effect of these herbicides on heterocyst frequency.

Ahmad, M.H., Venkataraman, G.S. (1973) Tolerance of *Aulosira fertilissima* to pesticides. *Curr. Sci.* 42: 108 (Abstract).

Notes: *In vitro* experiment showed that all tested herbicides (MCPA, MCPB, Stam F-34) and most of the insecticides (Lindane, Parathion, Endrin, Diazionone, BHC, Sevin) had no adverse effect on algal growth at recommended dose for application (1–2 ppm). Most insecticides had a stimulatory effect on *Aulosira* growth at concentrations lower than 10 ppm. Only BHC reduced algal growth by 50 percent at 1 ppm.

Amla, D.V., Kochhar, V.K. (1982) Physiological and genetic effects on some common phenylalkylureas on nitrogen fixing cyanobacterium *Nostoc muscorum.* In *Proc. Natl. Symp. Biol. Nitrogen Fixation,* IARI, New Delhi p 606 (Abstract).

Notes: Herbicides chlorotoluron and diuron were found effective in inducing mutants (pigment deficient, nonfixing, and cyanophage resistant) of *Nostoc muscorum* to 50–100 fold above the background level.

Andreev, V.P., Maslov, Y.I. (1985) Adaptation to diuron of *Anabaena variabilis* and *Cyanidium caldarium* pigment structures. *Fiziol. Biokhim. Kult. Rast.* 17(3): 293–297.

Summary: Changes in the absorption spectra of *Anabaena variabilis* and *Cyanidium caldarium* induced by diuron (a herbicide) are compared under conditions of photoautotrophic and photoheterotrophic growing. These changes are shown to be of the adaptive character. Possible adaptation mechanisms are considered.

Andreev, V.P., Maslov, Y.I. (1988) Adaptation to diuron by the cyanobacterium *Anabaena variabilis* Fd. during long periods of cultivation. *Vestn. Leningrad Univ. Biol.* 0(4): 71–75.

Summary: Prolonged cultivation of cyanobacterium *Anabaena variabilis* in the presence of sublethal diuron concentrations shows a two-stage character of culture adaptation to herbicide action. The first relatively short-time stage includes physiological adaptation, the main visible characteristics of which is the increased ratio phycobilin/chlorophyll. In the second, more prolonged stage intrapopulation selection of sells with low diuron-sensitivity, having low ratio phycobilin/chlorophyll is observed.

Arvik, J.H., Hyzak, D.L. Zimdahl, R.L. (1973) Effect of metribuzin and two analogs on five species of algae. *Weed Sci.* 21(3): 173–175.

Summary: Growth response of five species of soil algae to 4-amino-6-tert-butyl-3-(methyithio)-as-triazin-5(4H) one (metribuzin) and its 6-isopropyl and 6-cyclohexyl analogs were studied *in vitro*. Species of *Chlorella, Chlorococcum, Chlamydomonas, Anabeana* were exposed to 0.05, 0.1, 0.5 and 1.0 ppm (w/v) of the herbicides in liquid nutrient, while a species of *Schizothrix* was studied at the same levels in soil culture. With one exception, the growth and numbers of all of the algae were significantly reduced by increasing herbicide concentrations. *Anabaena* was not affected by 0.05 ppm of the cyclohexyl analog. No growth was permitted by any of the herbicides at 1.0 ppm. *Chlorella* and *Chlamydomonas* could not grow in the presence of 0.5 ppm of metribuzin or the cyclohexyl analog. Differences in response to the triazinones were noted between species. *Chlamydomonas* was the most sensitive and *Anabaena* and *Chlorella* the most resistant.

Arvik, J.H., Willson, D.L., Darlington, L.C. (1971) Response of soil algae to picloram-2,4-D mixtures. *Weed Sci.* 19(3): 276–278.

Summary: The effects of an approximate 1:4 commercial mixture of 4-amino-3,5,6-trichloropicolinic acid (picloram) and (2,4-dichlorophenoxy) acetic acid (2,4-D) on a natural population of soil algae were studied at dosages of 0.28, 0.56, and 1.12 kg/ha of picloram. No change in the composition of the algal flora was noted over an 18-month period, regardless of dosage. *In vitro* studies indicated that mixtures of picloram and 2,4-D inhibited growth of *Chlorella vulgaris* Beyer. at concentrations above 100 ppm, but concentrations above 250 ppm were needed for growth inhibition of *Cylindrospermum licheniforme* (Bory) Kuetz. or *Chlorococcum* sp. Picloram alone inhibited all three algae at 50 ppm, while 2,4-D produced no inhibitory effects at concentrations less than 400 ppm.

Bahal, M. (1969) The effect of 2,4-Dinitrophenol on heterocyst development in *Anabaena ambigua*. *Phykos* 8: 11–17.

Summary: 2,4-dinitrophenol was found to stimulate the development of heterocysts in *Anabaena ambigua*. It was most effective at pH 7.3. The effect produced by DNP could be reversed by ammonium ions.

Batalla, J.A. (1975) *Algae in ricefields and use of algicides.* [in Spanish] Valencia, Federacion Sindical de Agricultores Arroceros de España. 57 pp. (NS)

Notes: Review of algae common in ricefields of Spain and the methods to control them, with emphasis on algicides. The first part of the paper summarizes taxonomy and physiology of ricefield algae. Then detrimental effects of algae and methods to avoid algal growth are presented. Batalla (1975) considers that most detrimental effects of algae are observed during the 30–40 first days of the crop cycle in direct seeded rice and during the first two to three weeks of the crop cycle in transplanted rice. Unicellular algae are usually not considered detrimental except for some muciagineous epiphitic algae that cover young germinating roots and refrain them to penetrate the soil. Batalla (1975) reports a detrimental effect of *Oscillatoria* sp. when forming a dense membranaceous mat, especially in seedbeds, that refrains gaseous exchanges between soil and water and refrains root penetration into the soil. Filamentous microalgae, especially those of net forming type, are detrimental in direct seeded rice at germination because of competition for light. They also have detrimental mechanical effects on young plants. Macrophytic algae (*Chara* sp.) are not considered to be often detrimental because they develop late in the crop cycle, when the rice plant is high enough not to suffers from mechanical disturbance or competition for light. In 1975, Batalla indicated that there were no algicides specially designed for utilization in ricefields but that most fungicides could be used as algicides. He listed six groups of algicides:

- Copper-based algicides including copper sulphate and copper oxycloride. Copper sulphate is used at 2–4 ppm/ha. A higher concentration (6 ppm) can be used for direct application on floating algal masses.
- Dithicarbamates (zineb, maneb, mancozeb, propineb, nabam, metiram)

commercialized as fungicides that can be used as algicides at dosages of 8–20 kg ai/ha.
- "Ftalimidas o derivados imidicos" (Captan, folpet, captafol) are basically cryptogamicides. They can be used as algicides at 3–4 ppm ai. A higher concentration 10–15 ppm was suggested for submerged aquatic macrophytes.
- Naphtoquinone derivatives (Diclone, Chironamid) applied at 3–4 ppm ai. Chironamid was reported to have no significant effect on floodwater invertebrates.
- Organic salts of tin (Fentin) applied at 3–5 kg ai/ha. Their high toxicity to warm blooded organisms refrains their utilization.
- Quaternary salts of ammonium (Dimanin, Hyamine) applied at high concentrations (10–40 ppm) of ai.

Algicides can be applied preventively on the seeds and in the water at the water inlet. For curative applications it is recommended to decrease the water level to about 5 cm before applying the algicide and to avoid irrigation for forty-eight hours. A list of eighteen algicides for use in ricefields is given together with toxicity levels for some freshwater fish.

Batterton, J.C., Bousch, G.M., Matsumura, F. (1971) Growth responses of blue-green algae to aldrin, dieldrin, endrin and their metabolites. *Bull. Environm. Cont. Toxicol.* 6: 589–594. (NS)

Notes: *In vitro* experiment on *Anacystis nidulans* and *Agmenellum quadruplicatum*. There was no effect of the tested pesticides at concentrations observed in aquatic environments (< 200 ppb). At higher concentrations a slight decrease in algal growth was observed but no algicidal effect. Results also show that degradation products of this insecticides might be as efficient/detrimental as the parent compounds.

Batterton, J.C., Bousch, G.M., Matsumura, F. (1972) DDT: Inhibition of sodium chloride tolerance by the blue-green alga *Anacystis nidulans*. *Science* 176: 1141–1143.

Summary: *Anacystis nidulans*, a freshwater blue-green alga, has been found to tolerate sodium chloride (1 percent by weight) and DDT [1,1,1-trichloro-2,2-bis-(p-chlorophenyl) ethane] (800 parts per billion) separately, but growth was inhibited in the presence of both compounds. This inhibition was reversed by an increased Ca concentration. It is possible that inhibition of (Na+, K+)-activated ATP-ase by DDT causes this species to lose the ability to tolerate sodium chloride.

Battino-Viterbo, A., Minervini-Ferrante, G., Bisiach, M. (1973) Comparison of activity of some chemicals on *Anabaena* and *Chlorella*. *Riso* 22(4): 327–336.

Summary: A series of *in vitro* tests on two algal strains of *Anabaena* and *Chlorella* isolated from Italian ricefields were carried out in order to determine the level of algicidal activity of some chemicals with a low toxicity to warm-blooded animals. Chlortalonil, Dichlorophen, and 2-dichloroacetamide-3-cloro-1,4- naphtoquinone were tested in comparison with triphenyl acetate (Brestan). In order to distinguish between algicidal and algistatic activity, the subculture technique was used. The activity of the various chemicals was characterized with the measure of the trend of cellular multiplication with the spectrophotometric technique. The experimental data were statistically analyzed in order to find the significant differences between the treatments. The trends of growth in function of time and dosages was interpolated with a curvilinear function; the functions were fitted on the experimental data with the multiple regression method. The most effective chemical at low dosage (1–2 ppm) which can be considered as a substitute of Brestan is 2-dichloroacetamide-3-cloro-1,4-naphtoquinone (HOE 2997).

Bednarz, T. (1981) The effect of 2,4-D acid on green and blue-green algae in unialgal and mixed cultures. *Acta Hydrobiol.* 23(2): 173–182.

Summary: Low concentrations of 2,4-D usually stimulated the growth of algae. Higher concentrations inhibited or stopped the growth. Chlorococcal green algae were more sensitive than filamentous green and blue-green algae. Two of four sensitive and tolerant species were grown together in mixed cultures treated with 2,4-D. Tolerant species decreased the toxicity of the herbicide to sensitive algae. The protective effect did not appear when *Scenedesmus acutus* was used as the tolerant species.

Bharati, S.G., Angadi, S.B. (1980) Studies on nitrogen fixing blue-green algae: their response to fungicides. Pages 40–42 in *Proceedings of the National Workshop on Algal Systems*. Indian Soc. Biotechnology, IIT/New Delhi 110016, India.

Summary: The longs and short-term effects of some commonly used fungicides like Captan, Agallol 3', Dithane-z-78 and Ceresan on algae were studied. It has been established that the nitrogen fixed by any species of blue-green algae is related to the numbers of heterocysts produced by it. Dithan-z-78 in concentrations of 0.5 and 0.1 g/ml produced fixed nitrogen twofold over the control. Cerasan on the other hand affects production of heterocysts and consequently fixes less of nitrogen, this effect is seen in all, more in *Haphalosiphon welwitschii*. An exception to this occurred when the blue-green algae were treated with Agollol 3' and Captan especially on *Anabena azollae* and *H. welwitschii*.

Bharati, S.G., Giriyappanavar, B.S. (1986) Effect of two insecticides on the growth of *Calothrix membranacea*, a nitrogen fixing blue-green alga. *J. Karnatak Univ. Sci.* 31: 28–33.

Summary: Two insecticides Rogar 30E and Dimecron enhance the growth of *Calothrix membranacea* at particular concentrations, the other concentrations have deleterious effect.

Birmingham, B.C., Colman, B. (1983) Potential phytotoxicity of diquat accumulated by aquatic plants and sediments. *Water Air Soil Pollut.* 19(2): 123–132.

Summary: The adsorption and desorption of Reglone A to freshwater algae, *Myriophyllum spicatum* and a soil-sand mixture, singly and in combination was examined to investigate the potential for phytotoxicity of diquiat residues in aquatic sediments. The diquat adsorption capacity of the aquatic plants ranged from 0.6–2.4 mg diquat g^{-1} dry wt. Of the adsorbed diquat 40–70 percent could be desorbed with 5 M NH_4Cl. The adsorption capacity of the soil system was ~ 2.5 mg diquat g^{-1} dry wt and ~ 35 percent of this diquat could be desorbed. Reglone inhibited the growth of blue-green algae (*Anabaena flos-aquae* and *Anacystis nidulans*) at concentrations > than 0.03 ppm. Eukaryotic algae were less sensitive, growth of *Navicula pelliculosa* was inhibited at concentrations exceeding 0.3 ppm and *Chlorella vulgaris* was unaffected by 3 ppm Reglone. In the presence of soil, growth inhibition by Reglone was eliminated. Reglone was added to a water-soil mixture system at levels up to 334 ppm to simulate chronic usage. *Anabaena flos-aquae* or *Lemna* sp. were used to bioassay the availability of the diquat adsorbed to this soil system. Significant growth inhibition of both bioassay plants was observed in soil treated with 33.4 ppm Reglone and the 334 ppm treatment was lethal. Residual phytotoxicity becomes apparent in this soil system at ~ 7 percent of the diquat adsorption capacity. The Reglone adsorption-desorption isotherm of a natural, organic lake sediment was measured to predict the number of Reglone treatments at the recommended application rate before residual phytotoxicity would become apparent.

Bisiach, M. (1972a) Laboratory algicidal screening for the control of algae in rice. *Riso* 21(1): 43–58 (Summary in Italian).

Notes: Filamentous BGA are quoted as possible detrimental algae in ricefields. However the *in vitro* tests of algicidal effect of Fentin acetate, Benzuride, Captafol, HOE 2997, Folpet, and MnO_4K are performed on *Spirogyra* sp., *Oedogonium* sp., and *Hydrodictyon reticulatum*, which are considered as the algae most detrimental to rice. Efficient concentrations range from 1 to 8 ppm however, the authors indicate that efficiency is higher *in vitro* than *in situ*.

Bisiach, M. (1972b) Preliminary laboratory tests for the control of algae in ricefields. *Riv. Patol. Veg. Ser.* 4, 8(2): 159–181.

Summary: A method of preliminary *in vitro* test to determine algicidal and algistatic activity of chemical compounds against the most common algal forms infesting ricefields is here described. Against *Spirogyra* sp., *Oedogonium* sp., and *Hydrodictyon reticulatum*, the following chemicals have been tested: Benzuride, Captafol, HOE 2997, Folpet and $KMnO_4$ at the concentrations 0.5–1–2–4–8 ppm. All the chemicals except Benzuride showed a marked algicidal activity. Particularly HOE 2997 (2, dichloroacetamido-3, chloro, 1,4 naphtoquinone) has a complete algicidal activity at 1 ppm against Oedogonium sp. and Hydrodictyon reticulatum and at 2–4 ppm against Spirogyra. The napthoquinone derivative is not phytotoxic for rice and on account of its very high DL50 (11,700–15,000 mg/kg) opens new interesting perspectives for the control of algae in ricefields.

Bongale, U.D. (1985) On the response of spore germination and growth of three nitrogen-fixing cyanobacteria, isolated from soils, to pesticides: An assessment as bioindicators. *Symp. Biomonitoring State Environ.* 190–196. (NS)

Notes: *In vitro* experiment testing the effect of Aldrex-30, Monochrotophos-36, Rogor-30, BHC-50, Dithane M-45, Deltan-75 and Phorate-10 on the germination of spores of *Nostoc microscopicum, Hapalosiphon welwitschii*, and *H. confervaceus*. Effect of pesticides is estimated through visual observations at fifteen and twenty-five days and fresh weight measurement at 65 days.

Braginskii, L.P., Beskaravainaya, V.D., Shcherban, E.P. (1979) Responses of freshwater phytoplankton and zooplankton to pesticides. *Izv. Akad. Nauk. SSSR Ser. Biol.* 0(4): 599–606.

Summary: Pesticides, with regard to their concentration level, may suppress or activate planktonic organisms. In both cases pesticide effects are revealed at temperatures not lower than 17°C. Phytoplankton [*Aphanizomenon* and *Anabaena*] was suppressed by pesticides at concentrations from 1–10 mg/l, but some susceptible components of zooplankton [*Microcystis aeruginosa*] were suppressed at concentrations from 10^{-1} to 10^{-2} mg/l, the effect being chronic in rapidly succeeding generations. Phytoplankton possess buffer properties with respect to pesticide resistance. Variations in the structure of biocenoses are mainly related to changes in dominant forms.

Butler, G.L. (1977) Algae and pesticides, *Residue Reviews* 66: 19–62.

Summary: Although the algae are generally not the intended recipients of most pesticide applications, they comprise an important segment of the ecosystem which may be affected. As might be expected, the algae are highly susceptible to herbicides (e.g., triazines and ureas) but they are also inhibited by insecticides and fungicides (e.g., organochlorines and quinones). Much of the information on the effect of herbicides on algae has come indirectly from the study of herbicidal mode-of-action. The number of studies on the interaction of pesticides and algae are on the increase but only a small number of the hundreds of commonly used pesticides have been tested. In order to increase our understanding of the effects of various pesticides on the growth of algae, there are several areas in which investigators will need to concentrate their efforts. The effects of combinations of pesticides with other pesticides, with heavy metals, or with organic compounds on artificially generated communities or natural communities of algae or algae with other aquatic microorganisms will need to be studied. Because most investigations using marine algae have been limited to the phytoplankton, future work should include the study of pesticide effects on the macroscopic marine algae. Also, emphasis needs to be directed towards stages in the reproductive cycle since gametes may be more susceptible than the purely metabolic, vegetative plant body.

Cameron, H.J., Julian, G.R. (1984 The effects of four commonly used fungicides on the growth of cyanobacteria, *Plant Soil* 78: 409–415.

Summary: Four fungicides used commonly in agriculture are shown to be inhibitory to the axenic cultures of several species of cyanobacteria. Thus, fungicides may limit the beneficial effect of these microorganisms on soil nutrition.

Chaudhari, P.R., Jayangouder, I., Krishnamoorthi, K.P. (1989) Response of some common freshwater algae to DDT applications. *Proc. Indian Acad. Sci. Plant Sci.* 99(3): 279–286.

Summary: Growth pattern of three common freshwater algae *Chlorella, Scenedesmus*, and *Spirulina* was studied under the influence of organochlorine pesticide DDT, under laboratory conditions. *Scenedesmus* was found to be sensitive to DDT doses and growth was inhibited maximally up to 42 percent after 96 h at 5 ppm concentration. This alga shows phenotypic variations also in its colony structure at 3 ppm concentration. *Chlorella* and *Spirulina* are found to be highly tolerant and no growth inhibition is recorded at all doses of DDT. On the other hand, growth of these algae is promoted over that of control under the influence of DDT.

Chen Pei Chung. (1986) Effect of herbicides on growth and photosynthesis in *Anabaena* CH_2 and CH_3. *Proc. Nat. Coun. Rep. China Part B Life Sci.* 10(3): 151–156.

Summary: At herbicides butachlor or bromacil concentrations even as high as 100 ppm, growth and physiological activities of *Anabaena* CH_2 cells were not significantly altered. Benthiocarb inhibited cellular chlorophyll content, nitrogen fixation, photosynthetic and respiratory activities of CH_2 seemed to proceed simultaneously. The growth and physiological activities of Anabaena CH_3 cells would also be repressed by benthiocarb. Butachlor inhibited nitrogen fixation prior to photosynthetic activity. Bromacil would somewhat interfere in its growth and physiological activities. Photosystem 1 activity of Anabaena CH_2 and CH_3 would be slightly inhibited by 6 ppm benthiocarb or 100 ppm bromacil, PS II activity was not interfered with contrarily. Herbicide butachlor (100 ppm) would inhibit 45 percent of PS I activity of CH_2, but slightly affect PS I activity of CH_3, and PS II activity of CH_2. Photosystem II activity of CH_3 would not be influenced by 100 ppm butachlor.

Chinnaswamy, R., Patel, R.J. (1983) Effect of pesticide mixtures on the blue-green alga *Anabaena flos-aquae*. *Microbios Lett.* 24(95/96): 141–144.

Summary: The effect of the herbicide basalin and insecticides benhexol and thiodan on the blue-green alga, *A. flos-aquae*, individually and in combination with the herbicide fernoxone, was studied. Benhexol and thiodan suppressed the growth promoting activity of fernoxone whereas basalin did not affect such activity. Inhibitory effects were also observed.

Chinnaswamy, R., Patel, R.J. (1984) Blue-green algae and pesticides. *Pesticides* 18(9): 5–11. (NC)

Chinnaswamy, R., Patel, R.J. (1986) Detoxication of herbicides by blue-green alage. *Indian J. Ecol.* 13(1): 5–9.

Summary: Two nitrogen fixing blue-green algae viz. *Anabaena flos-aquae* and *Nostoc* sp. were grown in media containing the herbicides basalin and fernoxone. *Sorghum vulgare* and *Lepidium sativum* were employed as test species to detect the detoxicating ability of the algae. Algal culture filtrates and herbicide solutions were used for seed germination tests. The usefulness of bioassays to study detoxification of herbicides is discussed.

Cooper, S.L., Wingfield, G.I., Lawley, R., Greaves, M.P. (1978) Miniaturized methods of testing the toxicity of pesticides to microorganisms. *Weed Res.* 18(2): 105–108.

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

Couture, P., Visser, S.A., van Coillie, R., Blaise, C. (1985) Algal bioassays: their significance in monitoring water quality with respect to nutrients and toxicants. *Schweiz. Z. Hydrol.* 47(2): 128–158.

Summary: The review focuses on the use of primary producers as a biological tool for evaluating the impact of damage by human activity (eutrophication toxicity) on the aquatic environment. Studies are discussed following a reductionist approach by using algal bioassays (*Selenastrum capricornutum*). Variations of algal growth potential (AGP) within watersheds shows the impacts of human activities such as agriculture and urbanization on water quality. The study of variation of the AGP in time allowed the investigation of the effect of abiotic (temperature flow rate) and biotic factors (indigenous primary production) on the concentration of nutrients potentially available to phytoplankton. Seasonal changes of the AGP have further shown the impact of non-point (runoff) or point source (sewage effluents) on the aquatic system. A staggered relationship was observed between AGP values and chlorophyll-a content of indigenous phytoplankton. Values obtained in the laboratory by means of this type of approach would therefore appear to be transferably to natural systems. *S. capricornutum* was also used to identify toxic characteristics of substances in pure form or used in formulations and effluents released into the environment. It was shown that the use of bioassays should use care when evaluating results from tests requiring pretreatment such as storage autoclaving and filtration. Cautious interpretation is also recommended in order to distinguish between effects of growth-limiting essential elements and the presence of toxic substances. In general it appears from this review that the AGP provides helpful information for a sound management of the aquatic environment.

Cullimore, D.R., McCann, A.E. (1977) Influence of four herbicides on the algal flora of a prairie soil. *Plant Soil* 46: 499–510.

Summary: Four herbicides (2,4-D, trifluralin, MCPA and TCA) were applied at two concentration levels to isolated cores of a grassland loam soil. After herbicide contact times of 1, 5, and 20 days, samples were taken and the algal population estimated both quantitatively and qualitatively using two selective mineral salts media. Thirty one genera of algae were identified as occurring in

the soil. Of these, *Chlamydomonas, Chlorococcum, Phormidium, Palmella,* and *Ulothrix* proved to be so sensitive to the four herbicides that they were rarely isolated from the cores after treatment. Other algal genera were found to be less sensitive, and the theoretical percentile sensitivity of fifteen genera was calculated. *Chlorella, Lyngbya, Nostoc,* and *Hantzschia* were found to be the most resistant algae, having percentile sensitivity to all four herbicides of less than 50 percent. Some algal genera varied in their sensitivity to each of the herbicides. *Scytonema* was sensitive to all of the herbicides except, 2,4-D, while *Tolypothrix* showed a greater tolerance to MCPA. In the top cm of the soil, the reduction in cell numbers experienced by many algal genera after herbicide treatment was offset by an increase in the population of *Chlorella. Stichococcus, Oscillatoria,* and *Spongiochloris* all exhibited the ability to recover rapidly after a reduction in cell numbers resulting from the application of one of the herbicides. An overall reduction in cell numbers was noted for the algae growing preferentially on a nitrogen-free medium (i.e. potential nitrogen-fixers).

Dar, G.H., Zargar, M.Y. (1988) Effect of cuproxol and carbendazim on *Gloeocapsa. Ind. J. Ecol.* 15: 2. (NC)

Das, B. (1977) Effect of herbicides and pesticides on the freshwater blue green algae, Ph.D. dissertation, Utkal University, Vani Vihar, India. (NC)

Das, B., Singh, P.K. (1977a) Detoxication of the pesticide benzenehexachloride by blue-green algae. *Microbios Lett.* 4: 99–102.

Summary: The nitrogen fixing blue-green algae *Anabaenosis reciborskii* and *Anabaena aphanizomenoides* were employed in detoxicating the toxic effect of a pesticide BHC in nutrient medium. A gradual loss in the toxicity of BHC was noticed when repeated inoculation and removal of the algae was ensured. Therefore, the pesticide could be detoxicated by repeated growing and removing blue-green algae from the pesticide containing medium.

Das, B., Singh, P.K. (1977b) Effect of 2,4-dichlorophenoxy acetic acid on growth and nitrogen fixation of blue-green alga *Anabaenopsis raciborskii. Arch. Environ. Contam. Toxicol.* 5: 437–445.

Summary: Sodium salt of 2,4-dichlorophenoxyacetic acid (80 percent active ingredient), commonly applied for the control of aquatic weeds, was used to observe its effect on the growth and nitrogen fixation of a heterocystous bloom forming blue-green alga *Anabaenopsis raciborskii.* A concentration of 10 g/ml of 2,4-D showed stimulation of growth and nitrogen fixation and these were almost unaffected in presence of its 100 g/ml in the medium. The alga could

tolerate up to 800 g/ml in liquid culture media with and without nitrate nitrogen and up to 90 g/ml on to agar plates. Nitrogen fixation was inhibited in presence of its higher concentrations.

Das, B., Singh, P.K. (1978a) Mutagenicity of pesticides in blue-green algae. *Microbios Lett.* 5: 103–107.

Summary: An attempt was made to screen the probable mutagenic action of an insecticide hexachlorocyclohexane (BHC) and a weedicide 2,4-dichlorophenoxy acetic acid (2,4-D) on nitrogen-fixing blue-green algae *Anabaenopsis reciborskii, Anabaena aphanizomenoides, Anabaena spirodies*, and on a non-nitrogen-fixing alga *Microcystis flos-aquae*. Three classes of morphological mutants, i.e. gas-vacuole-less (GV-), long filament forms (L forms) and straight filament forming (St forms) could be easily detected in untreated (spontaneously) and pesticide treated cultures. The slight increase in mutation frequencies was noticed after treatment with BHC, but 2,4-D treated cultures did not show any increase. The results suggested that BHC is mutagenically weak for blue-green algae whereas 2,4-D is non-mutagenic.

Das, B., Singh, P.K. (1978b) Pesticide (hexachlorocyclohexane) inhibition of growth and nitrogen fixation in blue-green algae *Anabaenopsis raciborskii* and *Anabaena aphanizomenoides*. *Zeit. Allg. Mikrobiol.* 18(3): 161–167.

Summary: The effects of the pesticide hexachlorocyclohexane (HCH) on the N_2 fixing blue-green algae *Anabaenopsis raciborskii* and *Anabaena aphanizomenoides* commonly found as blooms in fish ponds were studied. These algae were very sensitive to HCH, and a distinct decrease in growth rate was observed on prolonged incubation. Lower concentrations (10 g/ml) were algistatic and higher concentrations (60 g/ml) were algicidal. The inhibition of N_2 fixation indicated that the presence of HCH might affect overall nitrogen economy of inland waters.

Das, B., Singh, P.K. (1979) Relative tolerance of a bloom forming blue-green alga *Microcystis flos-aquae* (Wittr.) Kirchner to pesticides. *Nova Hedvigia* 63: 161–172.

Summary: The effects of herbicide 2,4 dichlorophenoxy acetic acid (2,4-D) and a pesticide benzene hexachloride (BHC) were studied on the growth of a bloom forming blue-green alga *Microcystis flos-aquae* commonly found in ponds. At the level of 10–100 g/ml of 2,4-D, growth of alga was stimulated but higher concentrations had depressing effects. The concentration of 100–1,000 g/ml were algistatic and 15,000 g/ml was algicidal. The concentration of 10 g/ml of BHC

did not affect the growth significantly whereas its higher concentrations showed inhibitory effects. The concentrations of 10–80 g/ml were algistatic and 100 g/ml was algicidal.

Das, S.S. (1976) Algal weeds and their chemical control: A review. *Indian J. Plant. Prot.* 4(2): 201–208.

Summary: Algal weeds *Chara* sp. and *Nitella* sp. are particularly responsible for considerable loss of paddy in West Bengal in low lying areas near the sea. Algal weeds are widely distributed throughout India except in dry desert areas of Rajasthan. Out of several algicides tried, copper sulphate, roccal, ferbam, dichlone, fentin acetate, nitrofen, zineb, tetrachloroisophthalonitrile, simazine, fentin hydroxide, 2,4, disodium ethylene bisdithiocarbamate (93 percent), Hoe 2873 (F), diquat, diquat dibromide, tri-butyl tinchloride with solubilizer, bis-(tri-n-butyltin) oxide with solubilizer and silver methane-aronate, hydrothol 191, simazine + prometryne W.P., diruron + – TCA, fenuron + – TCA, monuron + – TCA were effective in controlling various algae. Dichlobenil has proved to be a very promising preemergence herbicide for control of *Cladophora, Pithophora* and *Chara* sp. For controlling filamentous green algae *Oedogonium* sp. and *Rhizoctonium* sp. di-(N, N-dimethylcocoamine) and mono (N, N-dimethyl alkylamine) formulation of endothal proved the most effective.

DaSilva, E.J., Henriksson, L.E., Henriksoon, E. (1973) Effects of pesticides on asymbiotic and symbiotic nitrogen-fixing blue-green algae. Abstract (No. 14, p. 3), VI. International Conference in Global Impacts of Applied Microbiology. Sao Paulo, Brazil, July 1983.

Abstract: The effects of eight widely hitherto used pesticides comprised of one insecticide and seven herbicides were studied in five concs. (5–250 ppm) on the nitrogen-fixing capacities of nine asymbiotic cyanophycean species from the genera *Aulosira, Anabaena, Calothrix, Chlorogloea, Cylindrospermum, Nostoc,* and *Westiellopsis*. The phycobiont of the lichen *Collema tenax* was also used in the analysis. Whereas a stimulatory effect was observed in nitrogen-fixation in most forms a general pattern of gradual decline occurred at the end of a five-hour period. In general, phenylureas, phenoxyacetic acid and an organophosphorus compound were stimulatory initially in comparison to amitrole and the bipyridylium quarternary salts which had an adverse effect. In these short-term experiments a pronounced depression of cessation of nitrogen-fixation occurred in *Calothrix elenkinii* and *Cylindrospermum muscicola* with the quarternary salts. In long-term experiments following an initial static period of activity, most species recovered from their corresponding period of decline in short-term

experiments. The substituted ureas, monuron and linuron exhibited stimulatory effects in four forms.

DaSilva, E.J., Henriksson, L.E., Henriksson, E. (1974) Effect of pesticides on nitrogen fixation by blue-green algae. *Rev. Microbiol.* (S. Paulo) 5(4): 73–74.

Summary: Effect of pesticides amitrole and its derivative, monuron, linuron, digust, paraquat, MCPA, and of insecticide malathion on the abilities of nitrogen-fixation by green-algae *Anabaena cylindrica, Aulosira* sp., *Calothrix elenkenii, Chlorogloea fritschii, Cylindrospermum muscicola, Nostoc muscorum, Tolypothrix tenuis, Westiellopisis* sp., and the phycobiont, *Nostoc* sp.

DaSilva, E.J., Henriksson, L.E., Henriksson, E. (1975) Effect of pesticides on blue-green algae and nitrogen fixation. *Arch. Environ. Contam. Toxicol.* 3: 193–204.

Summary: The effects of the pesticides, amitrol, a derivative of amitrol (viz. 3–5-diamino-1,2,4-triazole), diquat, paraquat, linuron, MCPA, malathion, and monutron, were studied on the N_2-fixing algae, *Anabaena cylindrica, Aulosira* sp., *Calothrix elenkenii, Chlorogloeae fritschii, Cylindrospermum muscicola, Nostoc* sp. from *Collema tenax, Nostoc muscorum, Tolypothrix tenuis*, and *Westiellopsis* sp. In general, two types of response were discernible; an initial period of depression succeeded by an increased activity and an initial period of depression followed by a distinct decrease on prolonged incubation. The results indicate that some pesticidal compounds can severely limit the nitrogen-fixing capacities of blue-green algae, thereby affecting the overall nitrogen economy of soils in general.

Dhanarai, P.S., Kumar, S., Lal, R. (1989) Bioconcentration and metabolism of aldrin and phorate by the blue-green algae *Anabaena* (ARM 310) and *Aulosira fertilissima* (ARM 68). *Agric. Ecosyst. Environ.* 25(2/3): 187–194.

Summary: *Anabaena* sp. and *Aulosira fertilissima* showed marked ability to bioconcentrate aldrin and phorate from culture medium. Uptake was directly related to the insecticide concentration in the medium and was inversely related to the water solubility of the insecticides. Bioconcentration of aldrin in *Anabaena* sp. and *A. fertilissima* ranged from 3.9 to 247.5 g/g, respectively. Maximum concentration of aldrin in the blue-green algae was reached after 8–16 h and that of phorate after 16–32 h. Aldrin was metabolized to dieldrin by both blue-green algae but no metabolism was noticed in the case of phorate.

Dierksheide, W.C., Pfister, R.M. (1973) Uptake of dieldrin by two blue-green algae. *Abst. Ann. Meet. Amer. Soc. Microbiol.* p. 32 (NC)

Dooley, F., Houghton, J.A. (1974) The nitrogen fixing capabilities and the occurrence of blue-green algae in peat soils. *Br. Phycol. J.* 8: 289. (NC)

Dunigan, E.P., Hill, V. (1978) Studies on the use of chemicals to control algal surface blooms in rice floodwaters. *Louisiana Agric. Exp. Sta. Dept. Agron. Reports on projects for 1977*. Baton Rouge, La. 153–156. See next reference for summary.

Dunigan, E.P., Hutchinson, R.L., Hill, V. (1979) Can algal blooms be controlled in ricefield floodwaters? *Louisiana Agric.* 32(3): 3, 15.

Summary: The effects of the three chemicals on algal growth, rice grouth, yield, and Cu concentration in the rough rice seed from May through July 1977, was studied. Algal blooms were not a big problem in the summer of 1977; however, the data indicate that Bluestone (copper sulfate) and the copper-chelates gave significantly lower value for control of algal formation without adverse effects on vegetative rice growth or seed yield. Copper concentration in seed from the treated plots were slightly in excess of those in seed from the control plots, but none of the values was considered high. Because Bluestone was the only material that had an EPA clearance, it was used in small outfield plots at three farms near Abbeville, Chataignier, Crowley during the summer of 1977. These fields were selected because each had a previous history of prolific algal blooms during the early growing season. Although algal blooms were not heavy in 1977, the data did indicate that the early application of Bluestone before the first sign of a bloom aided in controlling the algal formation. No adverse effects on rice growth were noted, nor did the Bluestone applications cause any significant increases in the copper concentration in the grain. In summary, several chemicals were found to control algal blooms in ricefield floodwater. However, until further labeling is approved, Bluestone is the only algicide that can be used safely in ricefields. Test results indicated that if it was applied before a bloom started, or at the first sign of a bloom, it generally gave adequate control of the algae.

El-Haddad, M.E. (1984) Changes in metabolic activities of *Nostoc muscorum* and *Anabaena oryzae* in response to herbicide application. 1. Effect of molinate and benzthiocarb. Pages 277–285 in *Soil biology and conservation of the biosphere*, J. Szegi (ed.). Budapest: Akademiai Kiado. 2 v.

Summary: Two thiocarbamate herbicides, namely molinate /S-ethyl hexahydro-1 M-azepine-1-carbothionate/ and benzthiocarb /S-/4—chlorobenzyl/-N, N-diethyl thiocarbamate/ were tested for their effect on the growth and metabolic activities of *Nostoc muscorum* and *Anabaena oryzae*. Results indicated that molinate exerted

a stimulatory effect on growth yield, N_2-fixation, and chlorophyll a content of both algae, while in the presence of benzthiocarb, all these parameters markedly decreased. The changes of magnesium, phosphorus and sugar uptake, as well as dehydrogenase activity of both algae, in response to herbicide application were also followed.

El-Sawy, M., Mahmoud, S.A.Z., EL-Haddad, M.E., Mashhour, W.A., Salem, K.G. (1984) Effect of different herbicides on nitrogen fixation by blue-green algae in paddy soil. Pages 297–306 in *Soil biology and conservation of the biosphere*, J. Szegi (ed.). Budapest: Akademiai Kiado. 2 v.

Summary: Algal inoculation with *Nostoc muscorum* and *Anabaena oryzae* in paddy soils, as affected by the herbicides molinate, benzthiocarb, fluorodifen and propanyl was investigated. Different types of soils were used in this study. The response of algal inoculation in the presence of the mentioned herbicides was indexed by measuring plant height, number of leaves, shoot dry weight, total nitrogen content of shoot and percentage of soil nitrogen. Results revealed that there is no risk in the application of herbicides under study on the activity of the inoculated algae.

ElNawawy, A.S., El Fadl, M.A., Nada, M.M. (1962) Economical studies on algae in Egypt. I. Effect of new isothiouronium derivatives of arylmercaptoalkane carboxylic acids on the paddy soil flora of algae in Egypt. *J. Soil Sci. UAR* 2(1): 3–14.

Summary: The algicidal properties of the Na salt and six s-alkylisothiouronium salts of one of the arylmercaptoacetic acid were studied in a glucose-salts medium. The inoculant was a mixed algal culture which had been obtained from ricefields in Egypt. The s-alkylisothiouronium compounds at a concentration of 0.5 g anion/li destroyed all algae. Some were effective at lower concentrations. Reinoculation after 15 days revealed the persistence of all or some of the algicidal properties. The Na salt was less toxic to algae. All the compounds, at lower concentration, had a selective action, unicellular green algae being more resistant than filamentous forms.

Entzeroth, M., Mead, D.J., Patterson, M.L., Moore, R.E. (1985) A herbicidal fatty acid produced by *Lyngbya aestuarii*. *Phytochemistry* (OXF) 24(12): 2875–2876.

Summary: A herbicidal component isolated from ethanolic extracts of *Lyngbya aestuarii* was identified as 2,5-dimethyldodecanoic acid. It inhibited the growth of *Lemna minor* at concentrations higher than 200 ng/ml. Growth inhibition was strongly pH dependent.

Fitzgerald, G.P., Gerloff, G.C., Skoog, F. (1952) Studies on chemicals with selective toxicity to blue-green algae. *Sewage Ind. Wastes*. 24: 888. (NC)

Fitzgerald, G.P., Skoog, F. (1954) Control of blue-green algae blooms with 2,3-dichloro naphtho-quinone. *Sewage Ind. Wastes* 26: 1136. (NC)

Friedberg, D., Seijffers, J. (1988) Sulfonylurea-resistant mutants and natural tolerance of cyanobacteria. *Arch. Microbiol.* 150(3): 278–281.

Summary: The herbicide sulfometuron methyl (SM) inhibited the growth of the cyanobacterium *Synechococcus* sp. PCC7942, but not of *Synechocystis* sp. PCC6714. The inhibitory effect was alleviated by the simultaneous addition of valine, leucine and isoleucine. SM resistant mutants were isolated from *Synechococcus* 7942, two types of which were further analyzed. In these mutants, SM3/20 and SM2/32, the activity of acetolactate synthase (ALS)- a key enzyme in the biosynthesis of branched-chain amino acids-appeared 2600- and 300-fold, respectively, more resistant to SM than that of their wild type. Strain SM2/32 also exhibited a low level of ALS activity. Although the growth of the latter mutant was extremely inhibited by valine, the sensitivity of its ALS activity to feed-back inhibition by the amino acid was unaltered. At high concentrations valine inhibited growth of the wild type strains and of the mutant SM3/20. Isoleucine alleviated the valine-induced growth inhibition. Unlike that of *Synechococcus* 7942, the ALS activity of *Synechocystis* was found to tolerate high concentrations (100-fold) of the herbicide. The study confirms that the SM mutations are correlated with a cyanobacterial ilv gene.

Fritz-Sheridan, R.P. (1982) Impact of the herbicide magnacide-H (2-propenal) on algae. *Bull. Environm. Contam. Toxicol.* 28: 245–249 (NS).

Notes: *In vitro* tests on *Enteromorpha intestinalis, Cladophora glomerata*, and *Anabaena* sp. with concentrations ranging from 10 ppb to 10 ppm. Significant decrease in photosynthetic activity was observed with the three strains at concentrations higher than 70 ppm.

Magnacide is an herbicide used as algicide in freshwaters and irrigation canals.

Gadkari, D. (1987) Influence of the photosynthesis-inhibiting herbicides Goltix and Sencor on growth and nitrogenase activity of *Anabaena cylindrica* and *Nostoc muscorum. Biol. Fertil. Soils* 3(3): 171–178.

Summary: The influence of the photosynthesis-inhibiting herbicides Goltix and Sencor on growth and nitrogenase activity of *Anabaena cylindrica* and *Nostoc muscorum* was studied. The cyanobacteria were grown under N_2-fixing

photoautotrophic conditions. *A. cylindrica* was entirely inhibited even in the presence of low field concentrations (Sencor 10 ppm, Goltix 50 ppm). In contrast, Goltix (50 ppm and 100 ppm) and Sencor (10 ppm, 20 ppm, 50 ppm and 100 ppm) did not exert an inhibitory influence on growth and nitrogenase activity of *N. muscorum.* In the presence of normal field rates of the studied herbicides increased light intensities during incubation had no detrimental effect on *N. muscorum.* Only at 20 W/m^2 light intensity did the higher concentrations of Sencor (50 ppm and 100 ppm) cause partial inhibition for the first 10–12 days, which was compensated during subsequent incubation. The delayed inhibitory effects caused by higher concentrations of Goltix (200 ppm and 500 ppm) are supposed to be due to degradation product(s). In the natural environment other species of cyanobacteria may occur which are able to tolerate photosynthesis-inhibiting herbicides.

Gadkari, D. (1988a) Assessment of the effects of the photosynthesis-inhibiting herbicides diuron, DCMU, metamitron and metribuzin on growth and nitrogenase activity of *Nostoc muscorum* and a new cyanobacterial isolate, strain G4. *Biol. Fertil. Soils* 6(1): 50–54.

Summary: The influence of the photosynthesis-inhibiting herbicides Diuron, DCMU, metanmitron, and metribuzin in growth and nitrogenase activity of *Nostoc muscorum* and a new cyanobacterial isolate, strain G4, was studied. The experiments were performed under N_2-fixing photoautotrophic conditions. Both cyanobacteria showed a high degree of tolerance towards the herbicides tested. In the presence of metamitron (35, 70, and 140 ppm) and metribuzin (7, 14, 35, and 70 ppm) strain G4 proliferated as well as the control culture. Metamitron and metribuzin had no influence on the nitrogenase synthesis of strain G4 and *N. muscorum.* When treated with 1 uM DCMU, strain G4 and *N. muscorum* showed partial inhibition for the first few days, but entirely recovered during succeeding incubation. In the presence of 10 ppm Diuron, *N. muscorum* and strain G4, compared to the control, showed 30 percent and 80 percent nitrogenase activity, respectively.

Gadkari, D. (1988b) Effect of some photosynthesis-inhibiting herbicides on growth and nitrogenase activity of a new isolate of cyanobacteria, *Nostoc* G3. *J. Basic. Microbiol.* 28(7): 419–426.

Summary: The effect of the photosynthesis-inhibiting herbicides Goltix, Sencor, Tycor, Arelon, DCMU, paraquat and atrazine on growth and nitrogenase activity of a new isolate of cyanobacteria, *Nostoc* G3 was studied. *Nostoc* G3 was cultivated under N_2-fixing photoautotrophic conditions. The used herbicide concentrations were in the range or recommended field rates. In the presence of

Goltix (50 mg/l and 100 mg/l), Arelon (15 mg/l and 20 mg/l) and DCMU (1 uM) the growth and nitrogenase activity of *Nostoc* G3 was almost completely inhibited. The most severe inhibitory effect was observed in the presence of paraquat. Even 1 h treatment of 1 mg/l paraquat caused a total inhibition of growth for 4 weeks. In contrast, the herbicides Sencor (10 mg/l and 20 mg/l) and Tycor (10 mg/l and 50 mg l) did not cause inhibition of growth and nitrogenase activity. In the presence of atrazine (1 mg/l and 2 mg/l) the nitrogenase activity and the growth were partially inhibited. The results obtained in this study show that cyanobacteria occurring in natural environments are resistant against some of the photosynthesis-inhibiting herbicides.

Gangawane, L.V. (1979). Tolerance of Thimet by nitrogen fixing blue-green algae. *Pesticides* 13: 33–44.

Summary: Thimet 10 G was not deleterious to *Westiellopsis* sp., *Aulosira* sp., *Tolypothrix* sp. and *Calothrix* sp. at the concentration of 1000, 500 and 300 ppm a.i. respectively. *Nostoc* sp., however, did not tolerate even 1 ppm of Thimet.

Gangawane, L.V. (1980) Tolerance of N-fixing blue-green algae to Brassicol, Bavistin and Fytolan. *J. Indian Bot. Soc.* 59: 157–160.

Summary: Tolerance of five nitrogen fixing algae (*Westiellopsis* sp., *Aulosira* sp. *Nostoc* sp., *Tolypothrix* sp. and *Calothrix* sp.) to three fungicides (Brassicol, Bavistin and Fytolan) was studied. All species could tolerate fungicides at different concentrations. Higher concentration (500–1,000 ppm) of Brassicol were tolerated than Bavisitin and Fytolan. *Calothrix* sp. was complete sensitive to Bavistin while the growth of *Nostoc* sp., and *Tolypothrix* sp. was stimulated due to Bavistin at 100 and 50 ppm respectively. *Tolypothrix* sp. and *Aulosira* sp. were not affected in the presence of Brassicol and Fytolan. Germination of the seeds of rice varieties Suhasini, Surya and Satya was not affected by these fungicides except in few concentrations where only 5–10 percent reduction in the germination was observed. However, Bavistin stimulated root growth of all varieties and shoot length of Satya was promoted by all the fungicides.

Gangawane, L.V., Chaporkar, C.B., Khalil, K. (1982) Effect of fungicides on the production of ascorbic acid and nitrogen fixation by *Nostoc* sp. and *Tolypothix tenuis*. Pages 670–671 in *Proceedings of the National Symposium on Biological Nitrogen Fixation*, IARI, New Delhi. (Abstract)

Notes: Effect of captan, MBC, zineb, quintozene, copperoxychloride, and thiram on the production of ascorbic acid and nitrogen fixation by the two species.

Gangawane, L.V., Deshpande, J. (1981) Effect of the nematicide algae *Mastigocladus laminosus* and *Aulosira fertilissima. Pestology* 5: 31. (NC)

Gangawane, L.V., Kulkarni, L. (1979) Tolerance of certain fungicides by nitrogen fixing blue-green algae and their side effects on rice cultivars. *Pesticides* 13(5): 37–38.

Summary: Tolerance limits of *Westiellopsis* sp., *Aulosira* sp., *Nostoc* sp., *Tolypothrix* sp. and *Calothrix* sp. to Topsin-M, Rovral, Thiram and Duter were studied. There was variation in the tolerance limits of these microorganisms to the fungicides. All the organisms tolerated Topsin-M and Rovral but were complete sensitive to Duter even at 1 ppm. Thiram was tolerated by *Nostoc* sp. and *Tolypothrix* sp. only. The growth of *Wiestiellopsis* sp. was much more affected than in others in the presence of fungicides. The growth was not affected in *Aulosira* sp. and *Calothrix* sp. There was no considerable effect of Topsin-M and Thiram on rice cultivars Suhasini and Satya. Rovral increased shoot length of Satya.

Gangawane, L.V., Saler, R.S. (1979) Tolerance of certain fungicides by nitrogen-fixing blue-green algae. *Curr. Sci.* 48(7): 306–308. (NS)

Notes: MBC, Difolatan and Hexacap were tested on five strains of N_2-fixing BGA. Except for the inhibition of *Westiellopsis prolifica* by MBC, all the other fungicide × BGA combinations showed final tolerant concentrations ranging from 100 to 1000 ppm.

Gangawane, L.V., Saler, R.S., Kulkarni, L. (1980) Effect of pesticides on growth and heterocyst formation in *Nostoc* sp. *Marathawada Univ. J.* 19: 3. (NC)

Gapochka, L.D., Veselago, I.A., Levina, M.Z. (1987) Adaptive reactions of algae populations to the action of toxic substances. *Biol. Nauki.* (Mosc) 0(3): 74–80.

Summary: The adaptive reactions of alga populations to the toxic effect have been investigated by the functional triad method. The role of phenotypic and genotypic adaptation and the dynamics of their correlation during the algal adaptation to the toxic media has been revealed.

Ghost, T.K., Saha, K.C. (1988) Influence of carbofuran on the growth and nitrogen accretion of blue-green algae (cyanobacteria) *Aulosira fertilissima*. *Indian Agric.* 32(3): 153–161.

Summary: The influence of carbofuran on blue-green algae, *Aulosira fertilissima* was studied in relation to growth N_2-fixation and its forms of accumulation in culture medium and also in two soils (alluvial and lateritic) under waterlogged conditions. In culture medium, carbofuran at the concentration of 10 and 25 ppm significantly increased the chlorophyll content and biomass (dry weight) of the organism with a simultaneous increase in the biomass-nitrogen (intracellular) and extracellular nitrogen content in the culture medium. However, higher doses of carbofuran were found to be toxic in this respect. In soil cultures the tolerance limit of this algae to the concentration of carbofuran was found to be much higher. Nitrogen fixation was encouraged at all levels of insecticide application up to 200 ppm during one and half month of incubation period, although the magnitude of response varied in the two soils. Such algal N_2-fixation equally benefited the soil with the accumulation of hydrolyzable and available (NH_4 + NO_3N) forms of N. The net mineralization of N due to the growth of blue-green algae had also shown an increase in presence of carbofuran.

Gibson, C.E. (1972) The algicidal effect of copper on a green and a blue-green alga and some ecological implications. *J. Appl. Ecol.* 9: 513–518.

Summary: The effect of copper sulphate as an algicide is reviewed briefly. Experiments are described in which *Anabaena flos-aquae* and *Scenedesmus quadricauda* were exposed to different concentrations of copper sulphate. It was found that *A. flos-aquae* was more sensitive to copper than *Scenedesmus quadricauda*. The lethal concentration of accumulated copper was similar for both species. The sensitivity of *Anabaena flos-aquae* to copper varied with the stage of growth of the alga, becoming less sensitive as the culture aged. The implications of these results for the use of copper-based algicides are discussed.

Gingrich, J.C., Buzby, J.S., Stirewalt, V.L., Bryant, D.A. (1988) Genetic analysis of two new mutations resulting in herbicide resistance in the cyanobacterium *Synechococcus* sp. PCC 7002. *Photosynth. Res.* 16(1/2): 83–100.

Summary: Two herbicide-resistant strains of the cyanobacterium *Synechococcus* sp. PCC 7002 are compared to the wild-type with respect to the DNA changes which result in herbicide resistance. The mutations have previously been mapped to a region of the cyanobacterial genome which encodes one of three copies of psbA, the gene which encodes the 32 kDa Qbbinding protein also known as D1 (Buzby et al. 1987). The DNA sequence of the wild-type gene was first determined and used as a comparison to that of the mutant alleles. A point mutation at codon 211 in the psbA1 coding locus (TTC to TCC) results in an amino acid change from phenylalaine to serine in the D1 protein. This mutation confers resistance to atrazine and diuron at seven times and at two times the minimal

inhibitory concentration (MIC) for the wild-type, respectively. A mutation at codon 211 resulting in herbicide resistance has not previously been described in the literature. A second point mutation at codon 219 in the psbA1 coding locus (GTA to ATA) results in an amino acid change from valine to isoleucine in the D1 protein. This mutation confers resistance to diuron and atrazine at ten times and at two times the MIC for the wild-type, respectively. An identical codon change conferring similar herbicide resistance patterns have previously been described in *Chlamydomonas reinhardtii.* The atrazine-resistance phenotype in *Synechococcus* sp. PCC 7002 was shown to be dominant by plasmid segregation analysis.

Gleason, F.K., Case, D.E., Sipprell, K.D., Magnuson, T.S. (1986) Effect of the natural algicide, cyanobacterin, on a herbicide-resistant mutant of *Anacystis nidulans* R2. *Plant Sci.* (Shannon) 46(1): 5–10.

Summary: Cyanobacterin, a secondary metabolite produced by the cyanobacterium, *Scytonema hofmanni*, inhibits the growth of algae and plants. This compound is a potent inhibitor of photosynthetic electron transport and acts at a site in photosystem II (PS II). To further define the site of action of cyanobacterin, the effects of this natural product were investigated in a herbicide-resistant mutant of the cyanobaterium, *Anacystis nidulans* R2D2-X1. *A. nidulans* R2D2-X1 was reported to grow and maintain photosynthetic electron transport in the presence of 20 uM 3-(3,4-dichlorophenyl)-1, 1-dimethylurea (DCMU) and 6.0 uM atrazine. Resistance was attributed to an altered 32 kDa (quinone-binding, QB) protein [6]. In the presence of Hill electron acceptors, K3Fe(CN)6 and dichlorophenol-indophenol (DCPIP), spheroplasts of *A. nidulans* R2D2-X1 were exhibited by cyanobacterin at the same concentration as wild type spheroblasts. Under these same conditions, spheroplasts of the mutant maintained their resistance to DCMU. Similar results were obtained with isolated thylakoid membranes. In contrast, silicomolybdate reduction, which is resistant to DCMU inhibition, was very sensitive to cyanobacterin. We conclude that cyanobacterin inhibits electron transport in PS II at a unique site which is different from that of DCMU.

Golden, S.S., Haselkorn, R.H. (1985) Mutation to herbicide resistance Map within the psbA gene of *Anacystis nidulans* R2. *Science* 229: 1104–1107.

Summary: A pdsA gene encoding the target of photosystem II herbicide inhibition, the 30,000-dalton thylakoid membrane protein, has been cloned for a mutant of *Anacystis nidulans* R2, which is resistant to 3-(3,4-dichlorophenyl)-1, 1-dimethylurea- (Diuron). A cloned DNA fragment from within the coding region of this gene transforms wild-type cells to herbicide resistance, providing that mutation within pbsA is responsible for that phenotype. The mutation consist of a single nucleotide change that replaces serine at position 264 of the wild-type protein with alanine in that of the diuron-resistant mutant.

Goldsborough, L.G., Robinson, G.G.C. (1986) Changes in periphytic algal community structure as a consequence of short herbicide exposures. *Hydrobiologia* 139(2): 177–192.

Summary: Effects of the triazine herbicides simazine and terbutryn on total biovolume and community structure of haptobenthic periphytic algal communities within *in situ* marsh enclosures are described. Levels of biovolume inhibition in excess of 98 percent relative to an untreated control were observed at all levels of terbutryn tested (0.01, 0.1 and 1.0 mg/li). No reduction in total biovolume was observed at 0.1 mg/li simazine, with increasing inhibition (to 98 percent) at 1.0 and 5.0 mg/li. Following incidental enclosure flooding and removal of herbicide, increases in biovolume were observed in all but the highest treatment levels, with rates of colonization similar to that of the control. Pre-flood community structure of periphyton in simazine-treated enclosures was qualitatively similar to that of the control, while a small blue-green alga was abundant only in terbutryn-treated enclosures. After flooding, substratum colonization in most experimental enclosures was dominated by the diatom *Cocconeis plancentula*, while this taxon accounted for about 25 percent of total biovolume on substrata from the control and 0.1 mg/li simazine enclosures. It is concluded that periphyton successional processes, which normally lead to the development of a complex 3-dimensional mat, may be averted by short herbicide exposures.

Goulding, K.H., Wynne Ellis, S. (1981) The interaction of DDT with two species of freshwater algae. *Environ. Pollut. Ser. A Ecol. Biol.* 25(4): 271–290.

Summary: Whereas the growth of the blue-green alga *Anabaena variabilis* was unaffected by 1 g/ml DDT, the growth of *Chlorella fusca* was affected by 0.1 g/ml. The amount of inhibition varied with time and with the method of growth measurement. When growth was assessed by cell numbers it was maximally inhibited (75 percent) after 72 h by 1.0 g/ml DDT. After 200 h cell numbers were the same as the control. Subsequently they exceeded the control cultures. When growth was determined by chlorophyll a or total culture biovolume the new inhibition was more marked and growth only equalled that of the control at the end of the experiment (480 h). This apparent anomaly was explained by the observation that treated cells were considerably smaller and more ovoid than control cells. The initial inhibition of growth of *C. fusca* by 1.0 g/mt DDT was greater at lower initial cell inoculum sizes, but was not affected by pH aeration conditions or phosphate concentration of the growth medium. Both algae accumulated ^{14}C-DDT. The amount accumulated was much higher in *C. fusca* than in *A. variabilis*. Neither alga significantly metabolized DDT although cells of *C. fusca* contained a small amount of DDE after 480 h incubation with the insecticide.

Goyal, S.K. (1986) Interaction between pesticides and cyanobacteria. Pages 93–96 in Radhir Singh Naihawahe, H.S., Sawhney, S.K. (ed.), *Current status of biological nitrogen fixation research*. H.A.U. Hissar, India. (NC)

Grant, I.F., Eagan, F.A., Alexander, M. (1983) Pesticides to control Ostracod grazing on blue-green algae (*Cyanobacteria*). *Soil Biol. Biochem.* 15: 193–197.

Summary: Means to control ostracods grazing on blue-green algae (cyanobacteria) important in fixing nitrogen in flooded rice soils were studied. The relative acute lethal toxicity (LC48/50) to the ostracods *Cyprinotus carolinensis* and *Heterocypris luzonensis* grazing on *Tolypothrix tenuis* was 0.4 and 2.4 g/ml for carbofuran and 4.5 and more than 56.0 g/ml for lindane. Complete inhibition of grazing was achieved with 1.0 and 25 g carbofuran/ml and 0.1 and 5.6 g lindane/ml for *C. carolinensis* and *H. luzonensis*, respectively. Lindane at concentrations below 0.02 g/ml stimulated feeding by *C. carolinensis* on the alga. Breakdown of carbofuran markedly reduced its effectiveness as a measure to control grazing, but lindane did not rapidly lose its effectiveness. The toxicity of carbofuran to *C. carolinensis* feeding on *T. tenuis* was not affected by pH. The difference in ostracod responses to the pesticides, which may be associated with resistance acquired through previous exposure, is an important consideration in designing practical means to reduce grazing in paddy fields.

Grant, I.F., Roger, P.A., Watanabe, I. (1986) Ecosystem manipulation for increasing biological N_2 fixation by blue-green algae (*Cyanobacteria*) in lowland ricefields. *Biol. Agric. Hort.* 3: 299–315. AB Academic Pub. U.K.

Summary: An introduction to the soil/floodwater ecosystem of lowland ricefields is given. Two primary consumers are particularly important in limiting the growth and N_2-fixing activities of blue-green algae in irrigated rice; the Ostracoda (Class Crustacea) and the Pulmonata (Mollusca). Control of grazing by neem seeds *Azadirachta indica* A. Juss and cultural practices enhanced BGA biomass and increased N_2-fixation ten fold. Significant increases in rice grain protein occur if heterocystous algae bloom early in the rice cultivation cycle and grazing control is maintained over 40 days. A large positive N balance was obtained over three rice crops by using neem seeds to control grazing of BGA. Algal inoculants used in conjunction with grazer control failed to establish themselves, and factors otehr than grazing were considered responsible. Plant-derived pesticides showed great promise for sustainable agriculture.

Grant, I.F., Seegers, R., Watanabe, I. (1984) Increasing biological nitrogen fixation in flooded rice using neem. Pages 493–505 in Schmutterer, H. and Ascher, K.R.S. (eds.), *Natural pesticides from the neem tree and other tropical plants* G.T.Z. Eschborn, F.R.G.

Summary: The antifeedant properties of neem extracts to *Heterocypris luzonensis* Neale (Ostracoda) were investigated. These aquatic crustaceans are particularly successful in colonizing wetland ricefields, where they can limit the establishment, growth and N_2-fixing activities of blue-green algae. Passive aqueous extracts of neem seeds and Soxhlet extractions of neem seed or cake in acetone or water did not affect grazing of *H. luzonensis* on *Tolypothrix tenuis* (Cyanophyta) within 2 h of exposure. However, passive aqueous extracts of neem seed substantially reduced grazing after 4 days of exposure. A 1.6 ppm aqueous solution of a crude extract of azadirachtin (15–18 percent in acetone) inhibited feeding completely and instantaneously. Greenhouse pot experiments were designed to study the effect of alleviating ostracod grazing pressure on N_2 fixing blue-green algae by applying neem seed and neem cake to the floodwater. Total nitrogen (N) inputs and outputs of the plants/soil/water system were measured over five rice harvests and the positive N balances obtained were attributed to biological N_2 fixation. A highly significant and large positive N balance was obtained in soils streated with neem seed. Neem cake applications did not increase N balance significantly when compared with an untreated control. When algal growth was prevented by covering soils with a black cloth, only a small N balance was maintained. Nitrogen uptake by grain and straw from pots treated with or without neem seed or cake was similar, but that from soils covered by a black cloth was 30 percent less. Neem had no direct effect upon growth of the rice plant. Effects of neem application on N balance were considered with reference to N-fixation, antifeedant properties, and inhibition of nitrification.

Grant, I.F., Tirol, A.C., Aziz, T., Watanabe, I. (1983) Regulation of invertebrate grazers as a means to enhance biomass and nitrogen fixation of *Cyanophyceae* in wetland ricefields. *Soil Sci. Soc. Amer. J.* 47: 669–675.

Summary: The effect of invertebrate grazing on the growth and N_2 fixation of blue-green algae (Cyanophyceae) in flooded rice soils was investigated by depressing grazer populations. Grazers were controlled with commercial pesticides and seeds of neem (*Azadirachta indica*). Algal N_2 fixation and standing biomass were estimated by acetylene-reduction activity and chlorophyll a measurements. Suppression of ostracod (Ostracoda) grazing by Perthane or neem seeds tripled blue-green algal biomass and increased N_2 fixation rates 10-fold. In the absence of ostracods, free living blue-green algae multiplied rapidly early in the rice cultivation cycle to be succeeded by chlorophytes. Carbofuran was not an effective

control measure. Suppression of molluscan grazing had little effect. The population of tubificids (Tubificidae) was higher in the plots where algal growth was stimulated than in other plots. Total rice grain N was increased up to 37 percent when grazing was arrested.

Gregory, W.W., Reed, J.K., Priester, L.E. (1969) Accumulation of parathion and DDT by some algae and protozoa. *J. Protozool.* 16: 69. (NC)

Gupta, G.S., Saxena, P.N. (1974) Effect of panacide on some green and blue-green algae. *Curr. Sci.* 43(15): 492–493. (NS)

Notes: *In vitro* tests with 30 concentrations ranging from 1 to 80 ppm of panacide (Dichlorophen) on *Scenedesmus obliquus, Chlorella pirenoidosa, Myxosarcina spectabilis, Aulosira prolifica,* and *Nostoc* sp. Marked inhibitions were recorded at concentrations higher than 20 ppm for the eukaryotic algae and higher than 10 ppm for the *Nostoc* sp.

Gupta, S.L. (1983) Acid phosphatase and alkaline phosphatase activity in the cyanobacterium *Anacystis nidulans* under copper stress. *Folia Microbiol.* 28(6): 458–462.

Summary: The effect of lethal concentration of Cu ions on the activities of acid and alkaline phosphatases was investigated in the cyanobacterium *A. nidulans* and the cyanophage AS-1 resistant mutant. When the level of phoshate (periplasmic protein) and acid phosphatase (cytoplasmic protein). In the presence of Cu, the level of enzymes was low, suggesting that synthesis and activity were not completely abolished by Cu. This may be related to the permeability of cell membrane.

Gupta, S.L. (1985) Influence of inorganic nitrogen nutrients on copper toxicity in *Anacystis nidulans* and cyanophage AS-1 resistant mutant. *Bull. Bot. Surv. India* 27(1–4): 142–144.

Summary: The effect of different nitrogen sources on growth and copper toxicity was studied in the unicellular cyanobacterium *Anacystis nidulans* and Cyanophage AS-1 resistant mutant (An/AS-1). The mutant An/AS-1 was characterized by slow growth rate but was more sensitive to copper than its parent. In both the strains, the presence of high nitrate concentrations, which supported better growth of algae, reduced the algicidal effect of copper. However, other inorganic nitrogen sources such as nitrite and ammonium caused more inhibition and reduced the specific growth rate. Mean autotrophic productivity, estimated by ^{14}C-bicarbonate uptake in daylight, ranged from 0.30–2.8 mg $C/m^2/ha$.

Autotrophic productivity was reduced by 57–81 percent at 2.5 g/li CuT, 55–96 percent at 5 g/li CuT, and 81–100 percent at 10 g/li CuT. Heterotrophic productivity (based on dark 35S-sulfate uptake) was inhibited to a lesser extent (28–63 percent at 2.5 g/li CuT, 24–84 percent at 5 g/li CuT and 67–92 percent at 10 g/li CuT). The inhibition of autotrophic and heterotrophic productivity persisted through the year of exposure. Production in stream sections previously exposed to 2.5 and 5 g/li CuT increased to control levels within four weeks after dosing, but remained depressed for more than seven weeks after exposure to 10 g/li CuT. The specific rate of photosynthesis (mg C mg chlorophyll/a/h) of mature periphyton communities declined at all test concentrations of Cu, but the rate for periphyton on newly-colonized surfaces did not change. The species composition of benthic algae shifted during exposure to an assemblage more tolerant of Cu. *Achnanthes minutissima* and *Fragilaria crotonensis* were the primary replacement species on newly-colonized surfaces. The nitrogenase activity of blue-green algae was low, with controls ranging from 2.4–12 nmol $C_2H_2/m^2/h$. Nitrogenase activity was inhibited during the initial weeks of exposure by 5 and 10 g/li CuT. After nine months of exposure, control and Cu-treated sections did not differ. The rate of processing of leaf litter, estimated by microbial respiration and nutrient quality of litter of resident riparian woodland taxa, was inhibited at all test concentrations of Cu.

Hamdi, Y.A., ElNawawy, A.S., Tewfik, M.S. (1970) Effect of herbicides on growth and nitrogen fixation by alga *Tolypothrix tenuis*. *Acta Microbiol. Pol. B* 2(19): 53–56. (NS)

Notes: Hamdi et al. (1970) treated cultures of *T. tenuis* with 0.1, 1, and 10 times the recommended dose of Ordram, trifluralin, 2,4D, or Stam either at the time of culture inoculation or 10 days after inoculation. At both times and all concentrations there was a reduction in dry weight and N content measured after 35 days of growth, and a stimulation in chlorophyll content. Ordam; 0.25 ppm, 30 percent inhibition; 2.5 ppm, 30 percent inhibition; 25 ppm 80 percent inhibition. Trifluralin: 0.25 ppm, 25 percent inhibition; 2.5 ppm, 45 percent inhibition; 25 ppm 80 percent inhibition. 2,4D: 0.045 ppm, 25 percent inhibition; 0.45 ppm, 45 percent inhibition; 4.5 ppm 30 percent inhibition. Stam: 0.18 ppm, 25 percent inhibition; 1.8 ppm, 45 percent inhibition; 18 ppm total inhibition.

Hartz, P.H. Rochling, Mariouw-Smith, F. (1972) 2-dichloro-aceta-mido-3-chloro-1,4-naphthoquinone, a new algicide for application in rice and other cultures. *Meded. Fac. Landbouw-wetensch Rijksuniv Gent* 37: 699. (NC)

Hatfield, P.M., Guikema, J.A., St. John, J.B., Gendel, S.M. (1989) Characterization of the adaptation response of *Anacystis nidulans* to growth in the presence of sublethal doses of herbicide. *Curr. Microbiol.* 18(6): 369–374.

Summary: Cells of the cyanobacterium, *Anacystis nidulans*, were cultured in the presence of sublethal doses of the herbicides DCMU [3-(3,4-dichlorophenyl)-1, 1-dimethylurea] and terbutryn (a triazine). The responses observed were characteristic of photosynthetic organisms grown under low light conditions. The contents of the accessory pigment phycocyanin increased in relation to chlorophyll. Moreover, each dose of herbicide was correlated with defined changes in the pigment profile. Data obtained from chlorophyll fluorescence measurements indicated that the additional phycocyanin was functionally integrated into phycobilisomes, probably into newly formed phycobilisomes. The concentration of fatty acids in the total polar lipid fraction (per milligram chlorophyll) was greater in adapted than in control cells; nevertheless, the ratio of unsaturated fatty acids remained unchanged. Measurable rates of photosynthetic electron transport were similar among herbicide-adapted cultures and controls. These data are consistent with the hypothesis that herbicide treatment impaired electron transport, but that function was restored by the adaptation response. Furthermore, this response is conserved among cyanobacteria and higher plants, indicating that this flexibility is extremely significant to photosynthetic function.

Hawxby, K., Tubea, B., Ownby, J., Basler, E. (1977) Effects of various classes of herbicides on four species of algae. *Pest. Biochem. Physiol.* 7: 203–209.

Summary: *Chlorella pyrenoidosa, Chlorococcum* sp., *Lyngbya* sp., and *Anabaena variabilis* were cultured in Bold's basal medium. They were treated with 0.1, 1.0, and 10 M concentrations of 2-chloro-2', 6'-diethyl-N-(methoxymethyl) acetanilide (alachlor), 2-chloro-4-(ethylamino)-6-(tert-butylamino)-s-triazine (terbuthylazine), 2-sec-butyl-4,6-dinitrophenol (dinoseb), 1,1-dimethyl-3-(-trifluoro-2,6-dinitro-N-propyl-p-toluidine) (profluralin), 2 4-bis(isopropylamino)-6-(methylthio)-s-triazine (prometryne), and (2,4-dichlorophenoxy) acetic acid (2,4-D). Growth of all algal species tested was markedly reduced by the triazines. Alachlor, dinoseb, and fluometuron inhibited growth of some algae at higher concentrations while 2,4-D and profluralin did not inhibit growth at the concentrations tested. Photosynthesis was greatly inhibited by the triazines, even at the 0.1 M concentration. Fluometuron was very toxic to the blue-green algae but had less effect on the green algae tested. *Lyngbya* was most susceptible to photosynthesis reduction by the herbicides. The concentrations of herbicides tested had little effect on respiration of the algae species. It appears that effect on algal growth were due primarily to inhibition of photosynthesis rather than to other metabolic processes.

Holst, R.W., Yopp, J.H., Kapusta, G. (1982) Effect of several pesticides on the growth and nitrogen assimilation of the *Azolla-Anabaena* symbiosis. *Weed Sci.* 30: 54–58.

Summary: Of 15 pesticides evaluated in a screening test with respect to their effects on growth and nitrogen assimilation of the *Azolla mexicana* (Presl)—*Anabaena azollae* (Strasburger) symbiosis, the bipyridilium and phenolic herbicides at 0.1 ppm were the most detrimental, causing up to a 75 percent reduction in nitrogen fixation and nitrate reduction with little or no effect on growth. Chloramber [3-amino-2,5-dichlorobenzoic acid], and benomyl [methyl–1-(butylcarbamoyl)-2-benzimidazolyl carbamate] at 10.0 ppm caused an 84 to 99 percent reduction in nitrogen fixation without affecting nitrate reduction or growth. Simazine [2-chloro-4,6-bis(ethylamino)-s-triazine] at 10.0 ppm stimulated nitrate reduction 20 fold, causing a 99 percent reduction in nitrogen fixation. Growth and nitrogen assimilation were reduced at similar concentrations between 0.1 and 10 ppm for each of the other benzoic, triazine, dinitroanaline, and urea herbicides tested. Naptalam [N-1-naphthylphthalamic acid] was the only pesticide tested that had no effect on growth or nitrogen assimilation at 10.0 ppm.

Hutber, G.N., Rogers, L.J., Smith, A.J. (1979) Influence of pesticides on the growth of cyanobacteria. *Zeit. Allg. Mikrobiol.* 19(6): 397–402.

Summary: Two unicellular and two filamentous cyanobacteria were exposed under conditions optimal for photoautotrophic growth to 11 pesticides. Low concentrations (0.01 to 5 ppm) of diuron, atrazine, and paraquat inhibited growth. With MCPA, MCPP, 2,4-D, Milstem and Ethrel, marked inhibitory effects were achieved only at concentrations above 100 ppm. Growth was inhibited by DDT, glyphosate, and Thiram at intermediate concentrations. In some cases, the effective concentration of the pesticide varied considerably with the organism tested.

Ibrahim, A.N. (1972) Effect of certain herbicides on growth of nitrogen-fixing algae and rice plants. *Symp. Biol. Hung.* 11: 445–448. (NS)

Notes: *In vitro* test of four herbicides (Eptam 6-E, Stam F-34, Ordram, and Trifluralin) on blue-green algae *Tolypothrix tenuis* and *Calothrix brevissima.*

Inger, L. (1970) Effect of two herbicides on nitrogen fixation by blue-green algae. *Sven. Bot. Tidskr.* 64: 460–461.

Summary: 2,4-D and MCPA affect the nitrogen fixation by *Nostoc muscorum, N. punctiforme* and *Cylindrospermum* at concentrations recommended for field application but stimulated nitrogen fixation at 10^{-4} to 10^{-5} M concentrations.

Ionescu, A.L. (1985) Restructuring of algocenoses in the soil under the influence of herbicides. *Stud. Cercet. Biol. Ser. Biol. Veg.* 37(1): 47–52.

Summary: The utilization of herbicides in various crops influences the quantitative and numeric composition of the edaphic flora. Analyzing in time the phytocenosis structure (algocenosis, mainly) it was established that its remarking may indicate, with precision, the absence of active remanent ingredients of the herbicide used. The paper surveyed the experiments regarding the determination of total number of microorganisms, on a medium containing soil extract, the identification of the species, and the number of algae and also regarding the ability of mineralizing the humus and of nitrifying the N resulted.

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

Notes: Experiment in 200 ml beakers with 70 g soil and 170 ml distilled water. When lime and Pentachlorophenol (PCP) were mixed with the soil, BGA growth was stimulated by liming, not affected by 120 ppm PCP incorporated, and was retarded by 600 and 1200 ppm. Surface application of PCP with or without urea was depressive to BGA and diatoms with long residual effect. Low levels of gamma BHC inhibited diatoms but not BGA. NAC and Ruberon had no effect on algae. Chloropicrin affected all kind of algae.

Ito, K., Chiba, Y. (1978) Studies on preventive methods for film-like separating of surface soil at the paddy field with mixed use of herbicides. *Tohoku Agric. Res.* 23: 39–40.

Notes: (In Japanese with no English summary)

Kar, S., Singh, P.K. (1978) Toxicity of carbofuran to blue-green alga *Nostoc muscorum*. *Bull. Environm. Contam. Toxicol.* 20: 707–714.

Summary: Effect of commercial grade furadan (3 percent ai as carbofuran) was studied on the survival, growth and N_2 fixation of blue-green alga *Nostoc muscorum*. The lower concentration of furadan i.e. 25 g/ml enhanced survival, growth and N_2 fixation in the alga whereas these were gradually inhibited in higher concentrations (50–1,000 g/ml) and the presence of more than 1,200 g/ml was algicidal. The preliminary observations revealed that pesticide is biodegraded by the alga.

Kar, S., Singh, P.K. (1979a) Detoxication of pesticide carbofuran and hexachlorocyclo-hexane by blue-green algae *Nostoc muscorum* and *Wollea bharadwajae*. *Microbios Lett.* 10: 111–114.

Summary: The N2 fixing blue-green algae *Nostoc muscorum* and *Wollea bharadwajae* were employed in detoxification tests of the pesticides carbofuran and hexachlorocyclohexane containing growth media. It was observed that the toxic effect of these chemicals was reduced by repeated inoculation and removal of blue-green algae, which indicated that pesticides are accumulated or detoxified in the algal cells.

Kar, S., Singh, P.K. (1979b) Effect of nutrients on the toxicity of pesticides carbofuran and hexachlorocyclohexane to blue-green alga *Nostoc muscorum*. *Zeits. Allg. Mikrobiol.* 19(7): 467–472.

Summary: The effects of various levels of nutrients like potassium phosphate (dibasic), calcium nitrate, and calcium chloride, individually and in combinations, were studied on the toxicity of the commonly used pesticides carbofuran and hexachlorocyclohexane (HCH) in growth medium to the N_2-fixing blue-green alga *Nostoc muscorum*. It was observed that all these chemicals had some effects on toxicity. The toxicity of both carbofuran and HCH was reduced to some extent in the presence of higher concentrations of the nutrients when compared to normal levels of the chemicals in the medium. The higher doses of nutrients in combinations antagonized the effect of individual treatment and enhanced the toxicity of pesticides.

Kar, S., Singh, P.K. (1979c) Effect of pH, light intensity and the population on the toxicity of the pesticide carbofuran to the blue-green algae *Nostoc muscorum*. *Microbios Lett.* 21: 177–184.

Summary: The effect of pH, light intensity and population on the toxicity of the pesticide furadan (containing 3 percent carbofuran as the active ingredient) was studied on the N_2 fixing blue-green alga *Nostoc muscorum*. It was observed that all these factors had effects on the toxicity of the pesticide. The blue-green alga grew better in the pH range of 7.5–10, whereas the acidic pH of 5–6 retarded growth. The pesticide was more toxic to alga in the medium of pH 5–6, whereas reduction in toxicity was noticed in alkaline pH of 7.5–10. The alga grew slowly in a light intensity of 1,500 lux in comparison to a light intensity of 3,000 lux, and no growth occurred in the dark. The toxicity of the pesticide gradually decreased with increasing light intensity. The toxic effect of the pesticide was increased when the initial population level was low, and increasing the initial population reduced the toxicity.

Kashyap, A.K., Gupta, S.L. (1981) Effects of dichlone on growth, macromolecular synthesis and photosynthetic pigments in blue-green algae. *Acta Bot. Indica* 9: 265–271.

Summary: Effects of dichlone on blue-green algae *Anacystis nidulans* (unicellular, non-N_2 fixing), *Nostoc calcicola, N. muscorum* and *Anabaena cylindrica* (filamentous and nitrogen fixing) was investigated. Low concentrations of dichlone stimulated growth of all the blue-green algae, while decrease in specific growth was observed at higher concentrations. Date based on specific growth rates suggested that *A. cylindrica* was more resistant and *A. nidulans* was most sensitive while other species possessed sensitivity of intermediate level. Dichlone was found to affect pigment composition in all the algal strains where phycocyanin was the first component to be affected. Since addition of nitrate to the medium partially reversed the lethal effects of dichlone, it was suggested that N_2 fixation (in N_2 fixing species) was primarily affected by dichlone. Depletion of phycocyanin supported this notion. Nevertheless, inhibition of nitrogen could as well result from the blockage of primary processes of photosynthesis.

Kashyap, A.K., Pandey, K.D. (1982) Inhibitory effects of rice-field herbicide Machete on *Anabaena doliolum* and protection by nitrogen sources. *Z. Pflanzenphysiol.* 107(4): 339–346.

Summary: Machete [2-chloro-2',6'-diethyl-N(butoxymethyl) acetanilide], a ricefield herbicide, is toxic to the N_2 fixing blue-green alga *Anabaena doliolum.* While low concentrations (0.05 g/ml) had stimulatory effects, algal growth was completely inhibited at 20 g/ml machete. Sublethal concentration (5.0 g/ml) of the herbicide resulted in the decline of protein and phycobilin levels with no apparent effect on chlorophyll a, carotenoids carbohydrate, DNA and RNA. The herbicide inhibited heterocyst differentiation and nitrogen fixation. In contrast to vegetative cells, spores were more resistant to the herbicide. Since toxicity of the herbicide could be reversed by inorganic nitrogen sources (nitrate, nitrite and ammonium), it is suggested that N_2 fixation was sensitive to the herbicide.

Kaushik, B.D., Venkataraman, G.S. (1983) Response of cyanobacterial nitrogen fixation to insecticides. *Current Science* 52(7): 321–323 (NS).

Notes: *In vitro* study of the effect of gamma BHC, carbofuran, and Phorate on five BGA. Concentrations tested ranged from 1 to 100 ppm. Total chlorophyll content and acetylene reducing activity of the cultures were tested, showing stimulatory effects or no effects at concentrations corresponding to the field level of application.

Kayumov, V. (1963) Use of copper sulfate for control of algae on ricefields. *Kolkhoz. Sovkhoz. Proizv. Turkmenistana* 6: 37–38 (In Russian). (NC)

Kayumov, V. (1965) Use of copper sulphate in control of algae on ricefields. *Kolkhoz Sovkhoz Proizv. Tadzhikistana* 6: 54 (In Russian). (NC).

Khalil, Z., Mostafa, I.Y. (1986) Interactions of pesticides with fresh-water algae: 1. Effect of methomyl and its possible degradation by *Phormidium fragile*. *J. Environ. Sci. Health Part B Pestic. Food. Contam. Agric. Wastes* 21(4): 289–302.

Summary: The insecticide methomyl showed no significant effect on the growth of the freshwater alga *Phormidium fragile* up to a concentration of 112.5 ppm. However, at higher concentrations inhibition was observed. Biochemical analysis showed a gradual decrease in all nitrogen fractions, total carbohydrate content, chlorophyll a and carotenes contents. Furthermore, a considerable decrease in the amount of both soluble and insoluble phosphorus fractions was also observed. The organism was capable of degrading 48.6 percent of the applied radiolabelled insecticide of which only 0.1 percent of ^{14}C-activity was trapped as $^{14}CO_2$. Furthermore, the chloroform and aqueous fractions contained 50.4 percent and 35.0 percent, respectively of the initial radioactivity. Thin-layer chromatographic analysis showed the presence of three metabolites of methomyl one of which was identified as the oxime.

Khasanova, L.A., Vagner, I. (1988) Effect of sublethal copper ion concentrations on the cells of the cyanobacterium *Synechocystis aquatilis*. *Vestn. Leningr. Univ. Biol.* 0(1): 83–88.

Summary: The effect of sublethal concentration of copper ions on cyanobacterium *Synechocystis aquatilis* was studied. A decrease in salt tolerance was observed, suggesting disturbances in cytoplasmic membrane. In response to copper ions the growth rate and photosynthetic activity of *Synechocystis aquatilis* decreased.

Kerni, P.N., Shant, P.S., Gupta, B.B., Singh, D. (1984) Effect of granular butachlor on the functioning of blue green algae in paddy fields. *Pesticides* 18(10): 21–22.

Summary: Insignificant differences in crop yield of paddy, variety Ratna during 1976 to 1978 in Kharif seasons, revealed that weed eradication with 30 kg/ha of butachlor (G) did not effect normal functioning of blue green algae, when both were used simultaneously in paddy fields. However, 15 kg/ha of butachlor (G) which recorded the highest yield every year, elucidated a compromising dose for better functioning of blue-green algae when compared to various doses of the weedicide.

Kerni, P.N., Shant, P.S., Singh, D., Gupta, B.B. (1983) Effect of butachlor (G) on blue green algae in rice farms. *Science and Culture* (May): 138. (NS)

Notes: Field experiment on simultaneous utilization of BGA inoculation and herbicide. Both methodology and conclusions are questionable.

Khalil, K., Chaporkar, C.B., Gangawane, L.V. (1980) Tolerance of blue-green algae to herbicides. Pages 36–39 in *Proceedings of the National Workings of Algal Systems*. Indian Soc. Biotechnology, IIT/New Delhi 110016, India.

Summary: Tolerance of 2,4-D by *Mastigocladus laminosus* was more than 1000 ppm. Only 100 ppm of Tolkan and Basalin was tolerable to this alga. Growth was reduced considerably as the concentration of herbicides increased. However, 500 ppm of 2,4-D was found to be stimulatory. Nitrogen content in both the dry matter and culture filtrate were reduced two and ten folds respectively due to herbicides at the tolerance level. Heterocyst counts increased at 1 to 50 ppm due to 2,4-D while in other cases there was many fold reduction. *Tolypothrix tenuis* showed its tolerance at 500, 100 and 50 ppm to 2,4-D, Tolkan and Basalin respectively. Growth, nitrogen fixation and heterocyst formation were affected considerably, this being more prominent in Tolkan and Basalin respectively showing various growth levels. Growth was more affected due to Basalin while nitrogen fixation due to 2,4-D.

Kikuchi, R., Yasutaniya, T., Takimoto, Y., Yamada, H., Miyamoto, J. (1984) Accumultion and metabolism of fenitrothion in three species of algae. *J. Pestic. Sci.* (Nihon Noyaku Gakkaishi) 9(2): 331–338.

Summary: *Chlorella vulgaris, Nitzchia closterium* and *Anabaena flos-aquae* rapidly absorbed fenitrothion, O,O-dimethyl O-(3-methyl-4-nitrophenyl) phosphorothioate, from medium, and the maximum bioaccumulation ratio in terms of dry weight was 44, 105 and 53, respectively. On transference of these algae to fenitrothion-free medium, the concentrations of ^{14}C and fenitrothion decreased rapidly, with half-lives of 1–15 hr and 1–2.6 hr, respectively. *A. flos-aquae* metabolized fenitrothion most actively to its oxon and demethyl analogs and its phenol, whereas *C. vulgaris* decomposed the chemical not to the oxon analogs, but to demethylfenitrothion. In contrast, DDT showed higher accumulation ratios of 433–82,000 and longer half-lives of 17–201 hr under similar conditions.

Kobbia, I.A. (1982) Response of phytoplankton populations in some Egyptian irrigation drains to the aquatic weed herbicide "acrolein." *Egypt J. Bot.* 25(1–3): 41–68.

Summary: The effects of the herbicide "acrolein" of the phytoplankton populations in Egyptian drains were studied. The results show some statistically significant differences in standing crop biomass and Species Diversity Index (SDI) between treated and untreated sites. Cyanophycean members appeared to be the most tolerant phytoplankton organisms to acrolein followed by Bacillariophycean cells. They rapidly recover and restore their vitalities.

Kobbia, I.A., Salama, A.M., Shabana, E.F. (1987) Changes in growth, carbohydrate and nitrogen metabolic processes in *Anabaena flos-aquae* and *Phormidium fragile* (Cyanophyta), under the combined effect of amitrole and dalapon. *Cryptogam. Algol.* 8(1): 19–28.

Summary: The herbicide mixture of amitrole and dalapon appreciably attenuated the gain in dry weight of *Anabaena flos-aquae* (Lyngb.) Breb. but stimulated the growth of *Phormidium fragile* Gom. Chlorophyll a biosynthesis was arrested in both algae. The total carbohydrates were significantly lowered in *Anabaena*, but remarkably increased in *Phormidium*, a trend that was associated with a similar rise in polysaccharide level. The mixture particularly at higher doses, increased external nitrogen secretion, and nitrate uptake. The total nitrogen content was increased in both organisms. The gain in the total soluble nitrogen fraction, was always much higher than the gain in the total insoluble nitrogen fraction.

Kostlan, N.V. (1980) Effect of copper ion concentration on respiration intensity in Chlorophyta and Cyanophyta. *Ukr. Bot. Zh.* 37(3): 51–53.

Summary: Effect of Cu^{2+} on the aerobic respiration of blue-green alga *Spirulina platensis* (Gom.) Geitl, and green algae *Chlorella vulgaris* Beijer, strain 18 (autotroph) and *C. pyrenoidosa* Chick, strain G-9 (the pigment mutant) depending on the culture age and nutrition conditions. The green and blue-green algae differ sharply in sensitivity of aerobic respiration to the given inhibitor: in the green algae a considerable inhibition of this process was observed at the concentration of Cu^{2+} considerably lower than in the blue-green ones. The Cu^{2+} effect on the cytoplasmic membranes may reflect a specificity of the cell membrane systems of the algae differing in taxonomic position and a variability of these systems under the effect of physiological and ecological factors.

Kumar, D., Jha, M., Kumar, H.D. (1985) Copper toxicity in the freshwater cyanobacterium *Nostoc linckia*. *J. Gen. Appl. Microbiol.* 31(2): 165–170.

Summary: The effect of copper ($CuCl_2$ $2H_2O$) on growth, heterocyst frequency, acetylene reduction, H_2 production and photosynthetic O_2 evolution of *Nostoc* *linckia* was studied. Whereas copper inhibited growth and other physiological processes, it increased heterocyst frequency and H_2 production. We conclude that copper pollution could considerably alter nitrogen dynamics in freshwater systems.

Kumar, H.D. (1963) Inhibition of growth and pigment production of a blue-green alga by 3-amino-1,2,4-triazole. *Indian J. Plant Physiol.* 6: 150–155.

Summary: The growth and pigment production of the unicellular blue-green alga *Anacystis nidulans* are reversibly inhibited by relatively low concentrations of 3-amino-1,2,4-triazole.

Notes: 10 ppm had no effect while the next concentration tested (50 ppm) reduced growth measured after 10 days by about 95 percent.

Kumar, H.D., Singh, H.N. (1981) *Biological action of common herbicides on nitrogen fixing potential of paddy fields.* Final report DST Project No. 11 (44) 176 SERC, Centre of Advanced Study in Botany, Banaras Hindu University. pp. 1–21.

Summary: From our study lasting over three years it is obvious that the response of different organisms to different herbicides varies. In all the cases there was total cessation of growth of the tested organism at certain concentrations of the herbicide. Although the relative tolerance of the organisms to these agricultural chemicals showed a pronounced difference, the mode of action of the herbicide seemed to be similar as is clear from the study with organic sources. It has been reported that most of the herbicides affect photosynthetic process and in such study at least impairment of PS-II may be overcome by the exogenous supplementation of utilizable carbon source. Lasso and Machete were found to be ineffective in blocking the PS-II system. But Saturn and Simazine seem to affect PS-II and on addition of exogenous utilizable carbon sources the impairment in PS-II was overcome to some extent. Concomitant with the growth inhibition caused by Lasso and Machete there was absence of nitrogenase activity. Hence their adverse side effect on nitrogen process seems warranted.

Kumar, S. (1988) Effects of pesticides on nitrogen-fixing blue-green algae. Vol. 3. Pages 129–155. in *Pesticides and Nitrogen Cycle, Rup Lal and Sukanya Lal* (eds.). Boca Raton: CRC Press

Notes: A review with 139 references and summary of toxicity tests performed with 61 pesticides on various BGA.

Kumar, S., Lal, R., Bhatnagar, P. (1988) Uptake of dieldrin, dimethoate and permethrin by cyanobacteria, *Anabaena* sp. and *Aulosira fertilissima*. *Environ. Pollut.* 54(1): 55–62.

Summary: Blue-green algae showed a poor ability to pick up and concentrate dieldrin and dimethoate. However, the uptake and bioconcentration factor for permethrin was very high. The uptake of dieldrin by *Anabaena* and *Aulosira* ranged from 5.1 to 73.2 and 5.5 to 174.4 μg/g (ppm), respectively. The uptake of permethrin was from 9.0 to 249.7 and 4.6 to 1,422.5 μg/g by *Anabaena* and *Aulosira*, respectively. The highest bioconcentration factors for permethrin in *Anabaena* and *Aulosira* were 813 and 2,373, respectively. This was followed by the bioconcentration factor of dieldrin (620) and dimethoate (119) in *Aulosira fertilissima*.

Lal, S. (1984) Effects of insecticides on algae. Chapter 9 in *Insecticide microbiology*, Lal, R. (ed.), Springer-Verlag, Basel. (NS)

Lal, S. (1985) Interaction of blue green algae, a ciliate protozoan and yeast with DDT, fenitrothion and chlorpyrifos, Ph.D. thesis, Delhi University, India. (NC)

Lazaroff, N., Moore, R.B. (1966) Selective effects of chlorinated insecticides on algal populations. *J. Physiol.* 2: 56. (NC)

Lederman, T., Rhee, G.-Yull. (1982) Bioconcentration of a hexachlorobiphenyl in Great Lakes: planktonic algae. *Can. J. Fish. Aquat. Sci.* 39(3): 380–387.

Summary: The bioconcentration of 2,4,5,2',4',5'-hexachlorobiphenyl (HCB) was examined in the Great Lakes algae *Fragilaria crotonensis, Ankistrodesmus falcatus* and *Microcystis* sp. The bioconcentration factors varied with species, whether they were expressed in terms of cell number, dry weight, cellular C, or cellular lipid. The factors were in the range of 10^5–10^6 and increased with decreasing biomass. The existence of a mucilage layer in *F. crotonensis* was associated with a two-fold increase in the bioconcentration factor. Surface adsorption apparently contributed only slightly to the bioaccumulation of HCB. HCB desorbed from all species but at a much slower rate than its adsorption.

Lim, R.P. (1980) Population changes of some aquatic invertebrates in ricefields. *Trop. Ecol. & Develop.*: 971–980.

Summary: The effects of pesticide application on the aquatic invertebrate community in ricefields was studied over two growing seasons. A total of thirty-nine taxa were collected over the two growing seasons. The dominant groups were

the nematodes, ostracods, conchostracans, ephemeropterans, hemipterans and dipterans which comprised an average of 93 percent of the total fauna. In the plots that were untreated with pesticides nematodes, hemipterans and dipterans dominated while in plots treated with pesticides ostracods, dipterans and conchostracans predominated. Temporal changes, community structure and population of the invertebrate community were affected not only by pesticide application but by ploughing, fertilization and transplanting, and the development of aquatic macrophytes. Heterogeneity decreased with the abovementioned perturbations. Only the application of the carbofuran had any significant effect in decreasing the invertebrate population. Overall the population was higher in the pesticide treated plots. This was due to inter alia to the rapid recruitment of ostracods.

Lukowski, A.B., Ligowski, R. (1987) Cumulation of chloroorganic insecticides by Antarctic marine diatoms. *Pol. Polar. Res.* 8(2): 167–178.

Summary: In Antarctic summer 1983/84 samples of planktonic and attached diatoms were collected in the Admiralty Bay (King George Island, South Shetland Islands) as well as samples of planktonic diatoms in the region of Sough Orkneys, Drake Passage and Bransfield Strait (BIOMASS- SIBEX Project). Using gas chromatography Presidues of chloroorganic pesticides, namely the compounds of the DDT group and HCH isomers were determined. It was found that the highest values of the content of these compounds occurred in attached diatoms coming from areas continuously washed with water from the melting glacier, in planktonic diatoms from the samples of the Admiralty Bay and from strongly glaciated regions. A hypothesis that put forward that along with the direct atmospheric transport the release of the deposits of these compounds from ice and glaciers during their melting is an additional source of input of chloroorganic biocides into Antarctic waters. Diatoms are good indicators of this process.

Lundkvist, I. (1970) Effect of two herbicides on nitrogen fixation by blue-green algae. *Svensk. Botanisk. Tidskrift.* 64(4): 460–461. (NC)

Maharana, R.K., Dash, P.I., Padhi, S.B., Padhi, S.P. (1986) Effect of some pesticides on two nitrogen fixing blue green algae. *Geobios* (Jodhpur) 13(5): 185–188.

Summary: Effect of carbofuran, diuron and acephate was observed on nitrogen fixing blue green algae, *Westiellopsis prolifica* and *Anabaena* sp. These were more sensitive to diuron in comparison to others.

Mallipudi, L.R., Gleason, F.K. (1989) Characterization of a mutant of *Anacystis nidulans* R2 resistant to the natural herbicide, cyanobacterin. *Plant Sci.* (Shannon) 60(2): 149–154.

Summary: Cyanobacterin, a secondary metabolite produced by the cyano-bacterium, *Scytonema hofmanni*, inhibits electron transport at a site in photosystem II. It was previously shown that a DCMU-resistant mutant of *A. nidulans* R2 was still susceptible to cyanobacterin (Gleason et al., *Plant Science*, 46 (1986) 5–10). Apparently, cyanobacterin acts at a site different from that of DCMU and similar PS II inhibitors. To confirm this conclusion, a cyanobacterin-resistant strain of *A. nidulans* R2 was produced by nitrosoguanidine mutagenesis and selected by growth in the presence of 4.7 M cyanobacterin. Hill activity in mutant thylakoids was compared to that of the wild type membranes in the presence of ferricyanide and silicomolybdate as electron acceptors. Photosynthetic electron transport in the mutant membranes shows a high degree of resistance to cyanobacterin in both reactions. In contrast, the mutant exhibits the same susceptibility to DCMU inhibition as the wild type R2. Cyanobacterin acts at a unique site, inhibiting electron flow from quinone-A to quinone-B.

Mallison, S.M., Cannon, R.E. (1984) Effects of pesticides on cyanobacterium *Plectonema boryanum* and cyanophage LPP-I. *Appl. Environ. Microbiol.* 47(4–6): 910–914.

Summary: Cyanobacterium *Plectonema boryanum* IU 594 and cyanophage LPP-1 were used as indicator organisms in a bioassay of 16 pesticides. Experiments such as spot tests, disk assays, growth curves, and one-step growth experiments were used to examine the effects of pesticides on the host and virus. Also, experiments were done in which host or virus was incubated in pesticide solutions and then assayed for PFU. *P. boryanum* was inhibited by four herbicides: 3-(3,4-dichlorophenyl)-1, 1-dimethylurea (DCMU), 1,1-dimethyl-3-(-trifluoro-m-tolyl) urea (Fluometeron), 2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine (Atrazine), 2-(ethylamino)-4-(isopropylamino)-6-(methylthio)-s-triazine (Ametryn). One insecticide, 2-methyl-2-(methylthio)-propionaldehyde 0-(methylcarbamoyl)oxime (Aldicarb), also inhibited the cyanobacterium. Two insecticides inactivated LPP-1, 0,0-dimethyl phosphorodithioate of diethyl mercaptosuccinate (malathion) and Isotox. Isotox is a mixture of three pesticides: S-[2-(ethylsulfiny)ethyl]0,0-dimethyl phosphorothioate (Metasystox-R), 1-naphtyl methylcarbamate (Sevin) and 4,4'-dichloroalpha-(trichloromethyl) benzhydrom (Kelthane). Two pesticide-resistant strains of *P. boryanum* were isolated against DCMU and Atrazine. These mutants showed resistance to all four herbicides, which indicates a relationship between these phototoxic chemicals.

The results indicate that *P. boryanum* may be a useful indicator species for phototoxic agents in bioassay procedures.

Maloney, T.E., Palmer, C.M. (1956) Toxicity of six chemical compounds to thirty cultures of algae. *Water Sewage Works* 103: 509. (NC).

Mathur, R., Saxena, D.M. (1986) Effect of hexachlorocyclohexane (HCH) isomers on growth of, and their accumulation in, the blue-green alga *Anabaena* sp. (ARM 310). *J. Environ. Biol.* 7(4): 239–252.

Summary: The different isomers of HCH affected the growth of *Anabaena*, the beta-HCH was the most toxic of all the isomers of HCH and alpha-HCH, the least. The different isomers of HCH get accumulated to varied extent in the alga under similar experimental conditions. The maximum accumulation of delta-HCH was 13 ppm while that of gamma-HCH was only 0.62 ppm.

Maule, A., Wright, S.J.L. (1983) Physiological effects of chlorpropham and 3-chloroaniline on some cyanobacteria and a green alga. *Pest. Biochem. Physiol.* 19: 196.

Summary: Sublethal concentrations of the herbicide chlorpropham caused marked changes in a green alga and some cyanobacteria. Herbicide-treated cells of *Chlamydomonas reinhardii* were enlarged, contained numerous nuclei and starch bodies, and were surrounded by multilayered envelopes. The herbicide altered the pigmentation of *Tolypothrix tenuis* by disturbing the relative amounts of the phycobiliproteins c-phycoerythrin and c-phycocyanin. Photosynthesis in *Anacystis nidulans* and *C. reinhardii* was inhibited by chlorpropham and the herbicide also reduced the rate of nitrogen fixation by *Anabaena cylindrica.* 3-Chloroaniline, a metabolite of chlorpropham, was relatively nontoxic.

Maule, A., Wright, S.J.L. (1984) Herbicide effects on the population growth of some green algae and cyanobacteria. *J. Appl. Bacteriol.* 57(2): 369–379.

Summary: Six herbicides were tested for their effects on the population growth of a range of green algae and cyanobacteria by an easily replicated low-volume liquid culture technique using Repli-dishes. Diuron, propanil and atrazine were most inhibitory. Chlorpropham was more inhibitory to green algae than to cyanobacteria. The effects of chlorpropham and 3-chloroaniline, a metabolite, on populations of the cyanobacterium *Anacystis nidulans* and the alga *Chlamydomonas reinhardii* were monitored in larger scale batch cultures. Both compounds reduced the growth rate although in some cases there was partial

recovery. 3-Chloroaniline was less inhibitory than the parent herbicide chlorpropham.

Notes: *In vitro* experiment with seven green algae and six BGA, Chlorpropham: EC50 ranged from 15 to 40 ppm for BGA and 2 to 10 ppm for eukaryotic algae. Diuron: EC50 values were lower than 0.6 ppm in all cases; Propanil: EC50 values ranged from 0.1 to 2.65 ppm; Atrazine: EC50 values ranged from 0.06 to 5.4 ppm; Glyphosate: EC50 values ranged from 70 to 600 ppm; MCPA: EC50 values ranged from 90 to 300 ppm.

McCann, A.E., Roy Cullimore, D. (1979) Influence of pesticides on the soil alga flora. *Res. Rev.* 72: 1–31.

Summary: The soil algae probably form between four and 27 percent of the total microbial biomass in the soil and appear to fluctuate considerably with the changes in the soil's environment. These algae contribute in a very definite way to the carbon and nitrogen cycles in the soil and possibly also to the phosphorus cycle, but quantification of their roles in this cycle has yet to be firmly established. A survey of the literature for *in vivo* and *in vitro* studies on the effects of pesticides on soil algae reveals that most work has been performed using herbicides *in vitro* studies on a very selected range of algae. In reviewing these studies, the most damaging pesticide group affecting the soil algae are those herbicides which directly interfere in the photosynthesizing mechanisms of plants. Given the state of knowledge at this time, two techniques (slide implantation and soil dilution) have been recommended for the *in vivo* and *in vitro* studies of existing and new pesticides which could be applied to the soil. Some concern was expressed about the lack of information on possible synergistic effects of adding surfactants to pesticide mixtures. It was noted that much more research needs to be undertaken on the monitoring of the activity of soil algae as well as on the quantification of population and its components.

Notes: Bibliographic review with ninety references.

Megharaj, M., Prabhakara Rao, A., Rao, A.S., Venkateswarlu, K. (1990) Interaction effect of carbaryl and its hydrolysis product, 1-naphthol, towards three isolates of microalgae from rice soils. Agric. Ecosys. Environ. 31: 293–300.

Summary: Carbaryl and its major hydrolysis product, 1-naphthol, were applied singly and together, at equal concentrations, to a green unicellular alga, *Chlorella vulgaris*, and two cyanobacteria, *Synechococcuys elongatus* and *Nostock linckia*. The effect on cell number, chlorophyll a and total protein content were assessed. The toxicities of carbaryl and 1-naphtol towards C. *vulgaris* were similar while carbaryl was more toxic than 1-naphthol towards the cyanobacteria. The

cyanobacteria were generally more sensitive to the combinations of the toxicants. Carbaryl and 1-naphthol, at different concentrations, interacted significantly, yielding either additive or synergistic responses. All the concentrations tested in combination gave a synergistic action towards the growth and nitrogen-fixing activity of *N. linckia.*

Megharaj, M., Prabhakara Rao, A., Venkateswarlu, K., Rao, A.S. (1987) Toxicity of *Parthenium hysterophorus* extracts to *Chlorella vulgaris* and *Synechococcus elongatus. Plant Soil* 103(2): 292–294.

Summary: Aqueous extracts from leaf or inflorescence of *Parthenium hysterophorus* were either algistatic or algicidal to *Chlorella vulgaris* and *Synechococcus elongatus.* Root extract, however, enhanced the growth of the two algae, but a 2.5 percent level was algistatic to *S. elongatus.*

Megharaj, M., Venkateswarlu, K., Rao, A.S. (1986) Growth response of four species of soil algae to monocrotophos and quinalphos. *Environ. Pollut. Ser A Ecol. Biol.* 42(1): 15–22. (NC)

Summary: *Scenedesmus bijugatus,* a green alga, and three blue-green algae (Cyanobacteria), *Synechococcus elongatus, Nostoc linckia* and *Phormidium tenue* all isolated from a black soil, were tested for their growth response to monocrotophos and quinalphos, using either cell number or chlorophyll a as toxicity criteria. Monocrotophos was significantly toxic above 20 g/ml to *S. bijugatus,* but enhanced the growth of *S. elongatus,* at all concentrations (5 to 100 g/ml) tested. At 100 g/ml, monocrotophos was toxic to *N. linckia* and at 50 and 100 g/ml, to *P. tenue,* but lower concentrations increased the growth of these two algae significantly. Quinalphos above 5 or 10 g/ml exhibited an algistatic effect on *S. bijugatus, S. elongatus* and *N. linckia* and was algicidal to them at the higher concentrations. Quinalphos, however, resulted in a significant enhancement in the growth of *P. tenue* at all concentrations.

Megharaj, M., Venkateswarlu, K., Rao, A.S. (1987) Influence of cypermethrin and fenvalerate on a green alga and three cyanobacteria isolated from soil. *Ecotoxicol. Environ. SAF* 14(2): 142–146.

Summary: The effects of two pyrethroid insecticides, cypermethrin and fenvalerate, on a green alga (*Scenedesmus bijugatus*) and three species of cyanobacteria (*Synechococcus elongatus, Nostoc linckia,* and *Phormidium tenue*), all isolated from a black cotton soil, were studied using either cell number of chlorophyll a as toxicity criterion. All the four species were either unaffected or stimulated at 5 g/ml. Of the two insecticides, cypermethrin, at 10 to 50 g/ml,

inhibited *S. bijugatus* while these concentrations stimulated or only slightly inhibited the growth of *S. elongatus*. There was a significant inhibition in the growth of *S. bijugatus* and stimulation in *S. elongatus* with 10 to 50 g/ml fenvalerate. The growth of *N. linckia* was enhanced by both insecticides while *P. tenue* was significantly affected.

Megharaj, M., Venkateswarlu, K., Rao, A.S. (1988a) Effect of insecticides and phenolics on nitrogen fixation by *Nostoc linckia*. *Bull. Environ. Contam. Toxicol.* 41: 277–281. (NS)

Notes: *In vitro* test of monocrotophos, quinalphos, cypermethrin, and fenvalerate at concentrations ranging from 5 to 100 ppm. Results do not include a control with no pesticide.

Megharaj, M., Venkateswarlu, K., Rao, A.S. (1988b) Tolerance of algal population in rice soil to carbofuran application. *Current Science* 57(2): 100–103. (NS)

Notes: Experiment on 20 g soil samples in test tubes. Ten and twenty days after exposure to various doses of furadan, soil algae were enumerated by MPN. Results show that at recommended field level, carbofuran had no detrimental effect on algal populations, BGA were favored by the pesticide application.

Megharaj, M., Venkateswarlu, K., Rao, A.S. (1989a) Effects of carbofuran and carbaryl on the growth of a green alga and two cyanobacteria isolated from a rice soil. *Agric. Ecosys. Environ.* 25(4): 329–336.

Summary: Two methylcarbamate insecticides, carbofuran and carbaryl, were assessed for their effects on a green unicellular alga, *Scenedesmus bijugatus*, and two cyanobacteria, *Synechococcus elongatus* and *Nostoc linckia*, all isolated from a rice soil. In laboratory studies, both insecticides up to 20 g/ml concentration significantly increased the cell number of *S. bijugatus*. *Synechococcus elongatus* was highly sensitive, 5 g/ml of each chemical being lethal. Concentrations, up to 20 or 50 g/ml, of the two insecticides initially increased chlorophyll a in *N. linckia* significantly, which again led to a subsequent inhibition. In general, carbaryl was more toxic than carbofuran to all the test organisms.

Megharaj, M., Venkateswarlu, K., Rao, A.S. (1989b) Interaction effects of insecticide combinations towards the growth of *Scenedesmus bijugatus* and *Synechococcus elongatus*. *Plant Soil* 114: 159–163.

Summary: The interaction effects of insecticide combinations involving an organophosphate (monocrotophos or quinalphos) and a pyrethroid (cypermethrin or fenvalerate) were determined on the growth of *Scenedesmus bijugatus* (unicellular green alga) and *Synechococcus elongatus* (unicellular cyanobacterium). In general, an organophosphate and a pyrethroid in combinations interacted additively, antagonistically, and synergistically on the growth of the two phototrophic microorganisms. However, combinations of quinalphos and cypermethrin or fenvalerate yielded additive interaction response in only *S. bijugatus*.

Mehta, R.S., Hawxby, K.W. (1979) Effects of simazine on the blue-green alga *Anacystis nidulans*. *Bull. Environm. Contam. Toxicol.* 23: 319–326. (NS)

Notes: Study of the effects of simazine on RNA and ultrastructure of *Anacystis*.

Mikhailova, E.I., Kruglov Yu, V. (1973) Effect of some herbicides on soil algiflora. *Pochvovedenie* 8: 81. (NC)

Minervini Ferrante, G., Battino Viterbo, A., Bisiach, M. (1974) Agar plate technique for potential algicide screening. *Riso* 23: 13–18.

Summary: A method used for the evaluation of the eradicant action of fungicidal chemicals was adapted for the *in vitro* evaluation of compounds with algicidal activity. In this paper a series of tests using some low toxicity chemical compounds (2-dichloroacetamide-3-chloro-1, 4-naphtoquinone, Chlortalonil, Dichlorophen) against two cyanophyta commonly infesting Italian rice-fields, *Oscillatoria* sp. and *Cylindrospermum* sp., are reported. The method appears to be effective giving prompt and reproducible results. The experimental data were statistically analyzed in order to evaluate the significant differences between the dosages. The results obtained confirm the high activity of the naphtoquinone derivative which appears to be a possible alternative to the use of the tin compounds.

Mishra, A.K., Pandey, A.B., (1989) Toxicity of three herbicides to some nitrogen-fixing cyanobacteria. *Ecotoxicol. Environ. SAF* 17(2): 236–246.

Summary: The effects of some common ricefield herbicides, such as 2,4-dichlorophenoxyacetic acid (2,4-D), Machete, and Saturn, on the paddy field nitrogen-fixing cyanobacteria *Nostoc linckia, Nostoc calcicola, Nostoc* sp., and *Anabaena doliolum* were studied. These cyanobacteria were found to be more tolerant to 2,4-D (lethal doses 1,500–2,000 g/ml) than to Machete and Saturn (lethal doses 6–8 g/ml). The effects of these three herbicides on some physiological processes of *N. linckia* were studied. The 2, 4-D stimulated the growth and nitrogen fixation up to 100 g/ml concentration (a dose higher than the field dose, i.e., about 40 g/ml), recommended for field application. However, with Machete and Saturn this type of stimulation was not observed even at lower concentrations. Similarly, the uptake of nutrients, such as NO_3^- and NH_4^+, was also inhibited by Machete and Saturn. However, 100 g/ml 2,4-D stimulated the uptake of NO_3^- but not of NH_4^+; higher doses of 2,4-D inhibited the uptake of both nutrients. Factors such as pH, organic carbon sources (glucose and acetate), and amino acids were found to regulate the toxicity of all three herbicides to *N. linckia*. Lower pH enhanced the toxicity of all three herbicides, whereas higher pH (up to 9.0) lowered it. Glucose and acetate (each 500 g/ml) protected against the toxicity of 2,4-D and Saturn, but not against Machete. Whereas glutamine, arginine, serine, and tryptophan conferred upon *N. linckia* a greater protection against the toxicity of all three herbicides, methionine did not do so, and the presence of methionine with herbicide in the culture medium resulted in greater toxicity to *N. linckia* than that in the presence of the herbicide alone.

Moore, R.B. (1967) Algae as biological indications of pesticides. *J. Phycol.* 3 (Suppl): 4. (NC)

Morar, S.N. (1970) Development of algae in ricefields in connection with application of herbicides [in Russian]. In *Vazhneishie Probl. Selek. Orosheniia Risa*, Moskva, Kolos: 217–219. (NS)

Morton, L.H.G., Lovell, M.L., Mitchell, A.F. (1984) The effect of maceration on filamentous algae used for the testing of algicidal compounds. *Int. Biodeterior* 20(1): 33–36.

Summary: An account is presented of the effect of maceration on the growth on solid media of two filamentous test algae [*Trentepohlia* and *Oscillatoria*] known to foul paint surfaces. Maceration had little effect on algal viability, showing that macerates of filamentous algae may be used in algicidal assay procedures. An assay procedure using filter paper discs impregnated with Nuodex 87 is outlined.

Mukherji, S.K. (1968) Chemical control of algae in West Bengal paddy fields. *World Crops* 20(1): 54–55. (NS) (see Mukerji and Laha, 1979)

Mukherji, S.K. (1970) Further studies on the chemical control of algal weeds. *World Crops* 22(6): 287–288. (NC) (cited in Das, 1976)

Mukherji, S.K. (1972) Use of pentachlorophenol as an algicide in paddy fields in West Bengal. *Weed Res.* 12(4): 389–390. (NS)

Mukherji, S.K., Laha, J.N. (1979) Effect of different chemicals used as algicides for control of algal weeds in lowland aman paddy field of coastal belt of West Bengal. *Pesticides* (July) 79: 54–55.

Summary: In a field trial for a year, application of Machete 5 percent granules (at 50 kg/ha) copper sulphate (at 12.50 kg/ha) as well as Dithane M-45 (at 6.25 kg/ha) were found most effective in controlling algae in lowland paddy field and they also thus gave increased grain yields. Lasso did not prove to be an effective algicide.

Notes: The authors report significant increase in yield when controlling *Chara* and *Nitella* by various algicides. Machete, copper sulphate, and Dithane controlled algae and increased yield by 47 percent, 26 percent, and 24 percent respectively. Lasso had no effect no algae and yield.

Mukherji, S.K., Ray, B.K. (1966) Algal weeds of paddy fields of costal West Bengal and their control by a new chemical. *Z. Pfl. Krankenheit u. Pfl. Schutz.* 73: 35–40. (NC) (cited in Das, 1976).

Mukherji, S.K., Sengupta, S.K. (1964) Control of algal weeds in paddy fields of West Bengal, India. *FAO Plant Protection Bull.* 12: 129–130. (NC) (cited in Das, 1976)

Muzafarova, D.A., Kuchkarova, M.A. (1971) Effect of herbicides on the algoflora of rice paddies. *Biol. Ekol. Georg. Sporovykh. Rast. Srednei. Azii.*: 145–146. (NC)

Notes: In Russian with no English summary.

Noll, M., Bauer, U. (1973) Rapid sensitive herbicide bioassay by inhibition of trichome-migration of blue-green algae. *Zbl. Bakt. Hyg., 1 Abt. Orig B* 157: 178. (NC)

Padhy, R.N. (1985) Cyanobacteria and pesticides. *Res. Rev.* 95: 1–44.

Summary: Most of the studies of effect of pesticides on cyanobacteria are carried out in the laboratory. *Anabaena* was more sensitive to DDT compared to *Anacystis microcystis*. In field conditions BHC stimulated growth of cyanobacteria by suppressing green algae. *Cylindrospermum* was most sensitive to BHC. *Agmenellum* was inhibited by low concentrations of endrin, but not *Anacystis*. Of course, *Agmenellum* had a better tolerance towards aldrin and dieldrin compared to *Anacystis*. Parathion at levels 1 to 5 ppm was harmless to N_2-fixing cyanobacteria in fields. Diazinon inhibited growth of cyanobacteria at

levels above 400 ppm. Carbaryl inhibited growth of *Cylindrospermum* and *Nostoc* at 120 ppm; carbofuran was growth stimulatory at 25 ppm and was completely toxic to these two genera at 3,000 and 2,000 ppm, respectively. The bloom of *Microcystis* was cleared by dichlone at a higher level (30 to 55 ppm) compared to the levels used for elimination of other cyanobacteria from fish ponds. Zineb inhibited growth of *Cylindrospermum* and *Nostoc* at 30 to 35 ppm in laboratory cultures but permitted growth of the majority of ricefield cyanobacteria at 100 kg/ha in field conditions. Ziram (2 to 6 ppm) eliminated N_2-fixing cyanobacteria in laboratory cultures. In field conditions, unlike other cyanobacteria, *Tolypothrix* and *Anacystis* tolerated 200 kg/ha Ceresan. In general, *Tolypothrix* had a higher tolerance capacity towards brassicol, bavistin, and fytolan. *Microcystis* and *Nostoc* can tolerate 2,4-D better compared to other genera. *Anacystis* had better tolerance capacity towards propazine and phenylurea herbicides (diuron and cotoron). *Aulosira* is reported to be most sensitive to most of the herbicides. *Tolypothrix* tolerated the highest level (below 18 ppm) of propanil. Light was essential to the herbicidal activity of the bipyridyl herbicides diquat and paraquat. Prometryn and symetryn had no adverse effect on cyanobacteria when applied in field conditions. In general, the cyanobacteria were reported to be sensitive to the antibiotics, particularly *Plectonema* to virginiamycin, and were less affected by copper sulfate. Morphometric studies with cells of *Plectonema* and *Anabaena* indicated the toxic actions of heavy metals in ultrastructure. Sodium chloride was reported to increase the toxicity of DDT to *Anacystis*; calcium had a beneficial effect in the reversal of this toxicity. Presence of combined nitrogen sources in growth media also had a toxicity-reducing effect on N_2-fixing forms. Fertilizers like urea and superphosphate reduce the toxicity of carbamate pesticides to N_2-fixing cyanobacteria (*Cylindrospermum* and *Nostoc*). In all available reports, there is a reduction in N_2 fixation in cyanobacteria by most pesticides. Napthalene is oxidized by *Oscillatoria* to 1-napthol. BHC, aldrin, DDT, carbaryl, carbofuran, Ziram, Zineb, Mancozeb, and parathion, etc. are reported to be taken up by cyanobacteria. The possibility of use of cyanobacteria in waste water is indicated. Cyanobacteria are not widely used for pesticide bioassay; trichrome migration in *Phormidium* was seen to be an effective method for this purpose. Mutagenicity testing has been done with cyanobacteria for very few pesticides which are not known yet to induce non-N_2-fixing mutants in cyanobacteria. Pesticide-resistant mutants of N_2-fixing forms (that are isolated) are indicated to be useful in maintenance of soil fertility and can be introduced into agriculture. It is discussed that there is difficulty in enumeration of cyanobacterial growth in field conditions.

Pal, R., Chatterjee, P. (1987) Algicidal action of diuron in the control of *Chara*, a rice pest. *Proc. Indian Acad. Sci. Plant. Sci.* 97(4): 359–363.

Summary: Diuron, a common algicide, was used in controlling the oospore formation of *Chara* species. Ten ppm solution of the chemical was found effective in controlling the sperm production in case of *Chara corallina* within 72 h of treatment. Fifty ppm solution was toxic to *Chara zeylanica* within 24 h of treatment. The threshold concentration (10–50 ppm) obtained did not affect the germination and vegetative growth of the rice seedlings since the transient effect was quickly reversed within a short time.

Palmer, C.N., Maloney, T.E. (1955) Preliminary screening for potential algicides. *Ohio J. Sci.* 55: 1. (NC)

Pande, A.S., Rekha, Sarkar, Krishnam-Oorthi, K.P. (1981) Toxicity of copper sulfate to the alga *Spirulina platensis*, and the ciliate *Tetrahymena pyriformis*. *Indian J. Exp. Biol.* 19(5): 500–502.

Summary: Effects of different concentrations of copper sulphate (as Cu^{2+}) on *S. platensis* and *T. pyriformis* were studied to determine the response of these fish food chain organisms to Cu. Aligicidal and aligistatic responses were determined in *S. platensis*. Further experiments were done to study the toxic effect of copper sulphate to *T. pyriformis* which will help to know the effective dose that will affect the simplest organism at the base of the fish food chain. Lethal, sublethal and LC_{50} (50 percent mortality in a specific period) values were recorded.

Pandey, A.K. (1985) Effects of propanil on growth and cell constituents of *Nostoc calcicola. Pest Biochem. Physiol.* 23: 157–162.

Summary: The ricefield herbicide, propanil, was toxic to the N_2-fixing cyanobacterium *Nostoc calcicola.* A decrease in growth was observed with the increasing concentrations of propanil, 30 g/ml being lethal. Since toxicity of the herbicide could be reversed by exogeneous supplementation of assimilable organic carbon glucose, it is suggested that carbon fixation was sensitive to the herbicide. The herbicide inhibited heterocysts differentiation and nitrogen fixation. There was a rapid decrease in total protein, nucleic acids (DNA, RNA), and carbohydrate content accompanied by a loss of photosynthetic pigments. The phycocyanin: chlorophyll a ratio showed positive correlation with increased dosages of the herbicide, suggesting the inhibition of chlorophyll a.

Pandey, A.K. (1987) pH dependent Saturn toxicity and nitrogen fixation of *Nostoc calcicola. Acta Bot. Indica* 15(2): 231–235.

Summary: The effect of pH on the toxicity of the ricefield herbicide Saturn was studies on the nitrogen-fixing cyanobacterium *Nostoc calcicola* under cultural conditions. The cyanobacterium survive in a wide range of pH (7–10). A progressive increase in the growth yield of the cyanobacterium was observed with increasing pH (7–10), attaining optimum at pH 9. The toxicity of the herbicide was reduced by raising pH (7–10) of the external medium. The elevated concentrations of the herbicide (2 to 4 g/ml) permitted growth and cell multiplication at or above pH 9 and the extremely low concentration (0.5 g/ml), reduced the growth of the cyanobacterium at neutral pH (7), showed a slight stimulation in growth at high pH (9–10). Heterocyst differentiation and nitrogen fixation was affected by the higher concentrations of Saturn while this effect was partially relieved by raising pH (7–10) of the medium with optimal values at pH 9. The results suggest that high pH are most effective in reducing the herbicide toxicity compared to neutral or low pH.

Pandey, A.K., Srivastava, V., Tiwari, D.N. (1984) Toxicity of the herbicide Stam f-34 (propanil) on *Nostoc calcicola. Z. Allg. Mikrobiol.* 24(6): 369–376.

Summary: The biological effect of the post-emergence ricefield herbicide Stam f-34 on the N_2-fixing cyanobacterium (blue-green alga) *Nostoc calcicola* has been studied under cultural conditions. The herbicide caused an inhibition of the N_2-fixing growth of the alga which was concentration-dependent and lethal at 30 g/ml. Both glucose and acetate quite efficiently reversed the inhibitory action of Stam f-34 even when it was present at a lethal dose. Also, an addition of the amino acids arginine, aspartic acid, serine, threonine and glutamine readily reversed the toxic effects of Stam f-34 even at lethal concentrations of herbicide (except glutamine). Low pH values enhanced the toxicity while high pH levels lowered the toxicity of herbicide to the alga. The herbicide was not mutagenic since it did not induce in the alga mutations to streptomycin and methylamine resistance.

Pandey, A.K., Tiwari, D.N. (1986) Action of 2, 4-Dicholorophenoxyacetic acid on *Nostoc linckia*: impact of glucose and tryptophan. *Folia Microbiol.* 31(1): 50–55.

Summary: 2,4-Dicholorophenoxyacetic acid (2,4-D) stimulated growth and heterocyst differentiation of *Nostoc linckia* in nitrogen-free medium at lower concentrations (100 g/ml) while its higher concentrations inhibited both processes and 1,500 g/ml provided to be lethal. Dry mass and specific growth rate of the alga declined with increasing concentration of 2,4-D in the range of 100–1,500 g/ml. Glucose slightly increased the heterocyst frequency without any lag in their differentiation. Tryptophan promoted growth of the alga and formation of heterocysts (nearly three-fold). Tryptophan (50 g/ml) complex medium with 1 mg 2,4-D/ml did not produce mature heterocysts. The filaments were fragmented at the point of heterocyst development and detached heterocysts germinated in situ. Glucose and tryptophan protected the alga, its growth and heterocyst differentiation even at the lethal concentration of the herbicide.

Pandey, K.D., Kashyap, A.K. (1986) Differential sensitivity of three cyanobacteria to the ricefield herbicide Machete. *J. Basic Microbiol.* 26(7): 421–428.

Summary: The effect of the ricefield herbicide Machete (2-chloro-2'6' -diethyl-N-(Butoxy methyl) acetanilide) on the growth and cell composition of *Anacystis nidulans, Nostoc muscorum* and *Anabena doliolum* was investigated. Growth of these cyanobacteria was completely inhibited at 2.5, 5.0 and 20 μg/ml, respectively, while a slight stimulation of growth was observed at lower concentrations. Stimulation of cyanobacterial growth in the presence of low concentrations of Machete was associated with an increase in the cellular levels of phycobilins and RNA while there was little impact on the levels of chlorophyll a and DNA. Photosynthetic pigments were degraded at lethal concentrations. The toxicity of the herbicide towards *N. muscorum* and *A. doliolum* could be reversed by supplementing the growth medium with either nitrate, nitrite or ammonia. This did not apply for *A. nidulans*. It is suggested that Machete inhibited N_2 fixation in the former two strains while nutrients availability was affected in the latter strain. In either case death, of the organisms was most likely due to nitrogen starvation.

Panigrahy, K.C. (1984) Physiological and genetical effect of pesticides on blue-green algae: effect of carbamate pesticides. Ph.D. dissertation, Berhampur University, India. (NC)

Paraschiv, M., Serbanescu, E., Popovici, G.h, Djendon, C. (1972) Algicide action of chemical substances on blue green algae. *Rev. Roum. Biol. Ser. Bot.*17: 195. (NC)

Patnaik, S., Ramachandran, V. (1976) Control of BGA with simazine in fish ponds. Pages 285–291 in *Aquatic weeds in Southeast Asia*, Varshney, C.K., Rzoska, J. (eds.), W Junk B.V. La Hague pub.

Summary: The paper describes field experiments conducted for controlling Microcystis bloom with simazine. The chemical was applied to the pond surface by means of foot pump sprayer at 200–400 l/ha. The bloom disappeared in 16–20 days with 0.25–0.75 ppm active simazine. The observations indicated that application of the chemical was not founds to cause any toxicity to fish

population. It is also non-toxic to zooplankton and other animal life in the pond. The cost of clearance worked out between Rs. 270–to Rs.438/ha. The dissolved oxygen in the treated pond may drop as a consequence of the decaying organisms which might cause distress to fish but the problem can be overcome by suitable precautionary measures.

Pattnaik, H., Prakash Rao, M. (1982) Effect of pesticides on growth and nitrogen-fixation of blue-green algae. Page 670 in *Proceedings of a National Symposium on Biological Nitrogen Fixation,* New Delhi.

Summary: The investigation is aimed at determining the effect of certain pesticides on growth and N_2 fixating ability of two blue-green alga, *Westiellopsis prolifica* and *Anabaena cylindrica* commonly found in the ricefields of Orissa. Different doses of pesticides have been used and it was found that at lower concentrations of pesticides the growth and N_2 fixing capacity of BGA are stimulated. The studies on the reversal of toxicity of pesticides using nitrogen carbon and phosphorus resources showed that, at certain critical concentrations of pesticides, the above resources can modify the toxic effects.

Pillay, A.R., Tchan, Y.T. (1970) The use of algae for the bioassay and study of tri-allate (herbicides). *Soil Biol.* 12: 20. (NC)

Pillay, A.R., Tchan, Y.T. (1972) Study of soil algae. Vll. Adsorption of herbicides in soil and prediction of their rate of application by algal methods. *Plant Soil* 36: 571–594.

Summary: Algal techniques were used to study the soil factors affecting the toxicity of herbicides. It was found that the organic matter adsorbed eighteen times more herbicide than clay. The inherent phytotoxicity of different herbicides was tested by these methods and the results obtained compared favorably to those of higher plants. The order of toxicity as tested by algae was: diuron > neburon > monuron > atrazine > simazine > atratone. The prediction of application rates of diuron and simazine by algal methods was tested in the field with wheat as cereal crop. The data obtained testified that the predictions were correct and better than the commercial recommendation. Good chemical control of weeds was achieved by herbicide at the early stage of crop growth. At later stages of crop development the toxicity of the chemical was reduced to insignificance and the crop plants were then capable to compete successfully against the emerging weeds. Thus a biological weed control was obtained. Such combined chemical-biological weed control technique should be regarded as the most desirable practice in agriculture.

Planas, D., Patrick, Healey, F. (1978) Effects of arsenate on growth and phosphorus metabolism of phytoplankton. *J. Phycol.* 14(3): 337–341.

Summary: The response to arsenate in growth and phosphate uptake by five algae in culture varied considerably. The growth rates of *Melosira granulata* var. *angustissima* O. Mull. and *Ochromonas vallesiaca* Chodat were depressed by 1 M arsenate. *Chlamydomonas reinhardtii* Dang. required 10 M for the same degree of depression, while the growth rates of *Cryptomonas erosa* Ehr. and *Anabaena variabilis* Kutz. were unaffected up to 100 M. However, following depletion of phosphate, cultures of the latter two algae began to die at the higher concentrations of arsenate tested. Growth of C. *reinhardtii* in the presence of 35 M arsenate resulted in characteristics of P deficiency. Comparison of rates of photosynthesis, respiration, and phosphate uptake between cultures of *C. reinhardtii* which had grown in the presence and absence of arsenate showed little evidence after 16 doublings that it had adapted to arsenate.

Prasad, A.B., Samanta, R., Vishwakarma, M.L., Vaishampayan, A. (1986) Biological effects of a mercury fungicide on a nitrogen-fixing blue-green alga *Nostoc muscorum*: Isolation and preliminary characterization of a mercury-resistant mutant. *New Phytol.* 102(1): 45–50.

Summary: Mercuric chloride, which is used as a fungicide in tropical paddy-fields, inhibits growth (in N_2, i.e. molecular nitrogen, and 5 mM KNO_3 media) and heterocyst formation (in N_2 medium) in the blue-green alga *Nostoc muscorum* at a concentration of 0.3 g/ml and above. These inhibitory effects were reversed on supplementation with 3 mM exogenous glucose. A mercury resistant mutant of this alga has been obtained, which is stable through repeated cell transfers in N_2 medium. It is suggested that a Hg-inducible protein/enzyme system is responsible for the intracellular mercury-resistance of this mutant.

Prescott, G.W. (1948) Objectionable algae with reference to killing of fish and other animals. *Hydrobiologia* 1: 1–13.

Notes: Contains a list of recommended doses of copper sulphate as an algicide.

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

Summary: The effect of additions of the gamma-isomer of benzene hexachloride (gamma-BHC) upon algal populations in two submerged tropical rice soils was studied. Additions of the insecticide to the floodwaters of the soils at 5, 6, and 50 kg/ha active compound resulted in a marked stimulation of growth of the

indigenous algae. The stimulation was attributed to the elimination by the insecticide of small animals which feed on the algae. No detrimental effect upon total algal populations was found when gamma-BHC was applied at 50 kg/ha, which is 10 times the rate recommended to control the rice stem borer. Qualitative changes were detected in the incidence of major algal groups. Blue-green algae were more abundant in treated soils whereas the green algae and diatoms were more abundant in the untreated soils. Much larger amounts of algal tissue were produced in the floodwaters treated with gamma-BHC. The possible effects of increased algal development on the fertility of the soil and the persistence of gamma-BHC in submerged soils are discussed.

Raghva Reddy, H.R. (1976) Studies on influence of pH, phosphate and pesticides on nitrogen fixation and radiocarbon assimilation by two blue green algae, M.S. thesis, University of Agricultural Sciences, Bangalore, India. (NC)

Rao, V.V., Narayana, S., Lal, R. (1987) Uptake and metabolism of insecticides by blue-green algae *Anabaena* and *Aulosira fertilissima*. *Microbios Lett.* 36(143/144): 143–148.

Summary: Blue-green algae *Anabaena* and *Aulosira fertilissima* rapidly accumulated and concentrated malathion and endosulfan from the medium. The uptake was linearly related to the insecticide concentration while bioconcentration was inversely related. Besides water solubility, stereo-chemical differences between isomers of endosulfan also influenced the uptake. Malathion was not metabolized by the algae, but endosulfan was converted to endosulfan ether and endosulfan lactone.

Rath, P., Choudhury, S.B., Misra, B.N. (1987) Effects of Emisan 6 (2-methoxyethyl mercury chloride) on the growth of *Westiellopsis prolifica* Janet. *Microbios Lett.* 34(135/136): 129–134.

Summary: The effect of Emisan-6 on the growth rate pattern of a blue-green alga, *Westiellopsis prolifica* Janet, was studied. A drastic reduction in the growth rate occurred at high concentrations and long exposure periods. Toxicity increased with increase in the exposure period. A negative correlation existed between the growth rate and pollutant concentration. Partial recovery in growth performance occurred when *W. prolifica* was transferred to mercury-free culture medium.

Rath, P., Panigrahi, A.K., Misra, B.N. (1985) Effect of pesticides on the photosynthetic efficiency of a blue-green alga, *Westiellopsis prolifica*. *Microbios Lett.* 29(113): 25–30.

Summary: The effects of the pesticides $HgCl_2$ and Emisan-6 (MEMC) on the photosynthetic efficiency of *W. prolifica* were studied. At lower concentrations of the Hg based pesticide, a significant increase in O_2 evolution occurred. With the increase in toxicant concentration and exposure period, a drastic decline was evident. The Hg based pesticide toxicity was totally dose/concentration dependent. At lower concentrations, Hg based pesticide toxicity was totally dose/concentration dependent. At lower concentrations, Hg acted as a growth regulator and at higher concentrations it acted as a growth inhibitor.

Ray, R.C., Sethunathan, N. (1988) Pesticides and nitrogen transformations in flooded soils. Vol. 2. Pages 119–142 in *Pesticides and nitrogen cycle*, Lal, R., Lal, S. (eds.)

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 studies is not uniform especially with regard to the concentration of 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, increasing the toxicity to insects. Evidently, for a meaningful conclusion, there is a need to generate data on 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 effect on pesticides, data were generated under laboratory conditions using relatively high pesticide concentrations. 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 N_2 fixation, which are carried out by a myriad of taxonomically different microorganisms. 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 N_2 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 rhizosphere soil and overall impact of such interactions on soil fertility.

Rohwer, F., Fluckiger, W. (1979) Effect of atrazine on growth, nitrogen fixation and photosynthetic rate of *Anabaena cylindrica*. *Angew. Bot.* 53: 59. (NC)

Saha, K.C., Mandal, L.N., Sannigarahi, S., Brandhopadhya, S. (1982) Effect of pesticide on nitrogen fixation and chlorophyll-a development in blue-green algae *Nostoc muscorum* and *Nostoc* sp. In *Proceedings of a Natlional Symposium on Biological Nitrogen Fixation,* IARI, New Delhi.

Abstract: The effect of pesticide, Phorate [O,O-diethyl S(ethylthiomethyl) dithiophosphate], containing 10 percent ingredient, on N_2 fixing activity and acetone extracted chlorophyll content due to inoculation of two species of BGA *Nostoc muscorum* and *Nostoc* sp. 2, in N-free media and alluvial rice soil were investigated in laboratory experiment. The lower concentration, 5–10 g/ml, encouraged the N_2 fixation and chlorophyll content over control in media.

Saha, K.C., Panigrahi, S., Bandopadhay, S.K., Mandal, L.N. (1984) Effect of phorate on nitrogen fixation by blue-green alga. *J. Indian Soc. Soil Sci. Agric. Chem.* 32: 79–83.

Summary: The effect of phorate (insecticide) on N_2 fixing blue-green algae, *Nostoc muscorum* and *Nostoc piscinale* was studied in liquid and soil culture systems. The fixation of N_2 and chlorophyll content of these algal cultures were markedly increased by the application of insecticide at lower concentrations. *N. muscorum* was more efficient than *N. piscinale* and performed well up to 50 μg/ml in liquid culture and at most levels (up to 250 μg/g) of insecticide application in soil culture. The toxicity of higher concentrations of insecticide was found to be gradually reduced on prolonging the growth period of the algal species.

Higher concentrations up to 250 μg/g soil and/or/ml medium were less lethal in soil culture than in liquid medium for both the algal species.

Salama, A.M., Kobbia, I.A., Shabana, E.F. (1984) Effect of sublethal concentrations of 2,4-D on the growth, carbohydrate and nitrogen metabolism of two phytoplankton from the Nile drains (Egypt). *Egypt. J. Physiol. Sci.* 11(1/2): 111–126.

Summary: The axenic cultures of either *Anabaena flos-aquae or Phormidium fragile* were subjected to various sublethal concentrations of 2,4-D in greenhouse chambers. The dry weight gain by both organisms was stimulated at lower levels and attenuated at higher concentrations. This trend was accompanied by a concomitant similar response in chlorophyll *a* biosynthesis, but with minor changes in the soluble sugar contents of the two algal masses. Lower and moderate levels of the herbicide induced a significant accumulation of polysaccharides and total carbohydrate contents, a trend that was attenuated at the highest dose of 2,4-D. The nitrate uptake by both algae was stimulated, accompanied generally with more nitrogen secretion and concomitant elevation in the total nitrogen contents, but the activation rate varied with the organism. Protein synthesis was accelerated under all treatments in *Phormidium* cells, but was remarkably suppressed at lower doses in *Anabaena* and slightly increased at high concentration. It is apparent that the stimulatory and/or inhibitory effects of 2,4-D on the growth of both algae were mainly correlated with the fluctuation of carbohydrate content, rather than disturbances in nitrogen metabolism.

Salama, A.M., Kobbia, I.A., Shabana, E.F. (1985) Growth, chlorophyll a content and metabolic responses of *Anabaena flos-aquae* and *Phormidium fragile* to the herbicide dalapon. *Egypt. J. Physiol. Sci.* 12(1): 53–66.

Summary: All concentrations of dalapon, except the highest, were generally accompanied with minor effects on the growth of dose (2700 ppm) caused a statistically significant drop in *Anabaena flos-aquae* and *Phormidium fragile*. The highest growth that was more prominent in *Anabaena*. Chlorophyll a biosynthesis was suppressed in *Phormidium* and fluctuated in *Anabaena* but was inhibited at the highest dose. Lower doses induced more accumulation of total carbohydrates, while higher levels suppressed its formation in both organisms. The nitrate uptake and total nitrogen content were stimulated by Dalapon in case of *Anabaena* but vice versa in *Phormidium.* The limited variations in the total insoluble nitrogen of *Anabaena* were mainly a result of respective changes in the other insoluble fraction and not the protein. The latter fraction, on the other hand, was accumulated in the cells of *Phormidium.*

Salem, K.G. (1980) Effect of some herbicides on nitrogen fixing blue-green algae. Ph.D. thesis, Faculty of Agriculture, Ain-Shams University, Cairo, Egypt. (NC)

Sardeshpande, J.S., Goyal, S.K. (1982) Effect of insecticides on growth and nitrogen fixation by blue-green algae. Pages 588–605 in *Biological nitrogen fixation*. Proceedings of a National Symposium, Indian Agricultural Research Institute, New Delhi. (NS)

Notes: The effect of Carbofuran, endosulfan, phorate, and gamma BHC (1, 5, 20, and 50 ppm) was tested on growth (optical density), and N_2 fixation (N accumulated) in cultures of *Anabaena iyengarii, Hapalosiphon intricatus, Calothrix membranacea*, and *Calothrix bharadwajae*. It was concluded that at the recommended doses of field application (0.3 to 1.5 ppm) these insecticides had no deleterious effect on the algae. Carbofuran and phorate at 1 ppm appreciably increased the growth and N_2 fixation of *A. iyengarii* and *C. membranacea*. Inhibitory effects was observed at concentrations higher than 5 ppm.

Satapathy, K.B., Singh, P.K. (1987) Effect of the pesticides carbofuran and phorate on the growth of water fern *Azolla pinnata* R. BR. varieties and their pests. *Beitrage trop. Landwirtsch. Veterinarmed.* 25(4): 411–417.

Summary: Water fern *Azolla pinnata* R. BR. is able to fix N_2 from the air and is therefore of increasing importance for the cultivation of rice. That is why this plant receives special attention in Asian countries as green manure. In a field trial the effect was tested of the insecticides carbofuran and phorate on the most important pests and the growth of *Azolla pinnata*. Four varieties were used from India, Vietnam, Thailand, and Bangladesh. Both insecticides were applied in concentrations of 0.075 and 0.15 kg ai/ha for the control of the larvae of *Nymphula responsalis* Walk. and *Cryptoblabes gnidiella* Mill. At the higher concentration carbofuran was found to significantly affect the development of the pests and the growth fern. Increased applications of phorate did not yield any improved effect. A comparison of the various provenances of *Azolla pinnata* showed that the variety from Bangladesh had a relatively higher tolerance to the pests. For the other varieties, control with carbofuran (0.15 kg ai/ha) is advised.

Schauberger, C.W., Wildman, R.B. (1977) Accumulation of aldrin and dieldrin by blue-green algae and related effects on photosynthetic pigments. *Bull. Environ. Contam. Toxic.* 17: 534–541. (NS)

Notes: Studied of the bioconcentration of aldrin and dieldrin at 1 g/li by *Anabaena cylindrica, Anacystis nidulans*, and *Nostoc muscorum*. After seven days, concentration of pesticides in algae ranged from traces to 1.3 μg/g for aldrin and from 0.2 to 1.8 μg/g for dieldrin, indicating a marked bioconcentration of both pesticides. Concentration up to 10 ppm aldrin or dieldrin in the culture medium had no marked effect on the growth of the three algae but higher concentrations were inhibitory.

Schluter, M. (1965) The effect of several fungicides and herbicides on freshwater algae under laboratory conditions. *Z. Fisch.* 314: 303. (NC)

Notes: Little effect of 20 to 60 ppm 2,4-D on cultures of three green algae, two BGA, and one diatom over a eight-week test period.

Shabana, E.F. (1985) Use of algal batch assays to assess the toxicity of atrazine to some selected blue-green algae: 1. Influence of atrazine on the growth, pigmentation and carbohydrate contents of *Aulosira fertilissima, Anabaena oryzae, Nostoc muscorum* and *Tolypothrix tenuis. Egypt. J. Physiol.* 12(1): 67–76.

Summary: The data presented in this investigation revealed that the gain in the dry weights of all test algae was suppressed under all herbicide treatments, particularly at higher concentrations. However, at the lowest dose of the herbicide, the growth inhibition was statistically significant in *Anabaena* and insignificant in the other algae. Chlorophyll a content in *Anabaena* was slightly and insignificantly increased at lower concentration; a phenomenon that was furthered by increasing the herbicide dose. On the other hand, the pigment biosynthesis was suppressed, under all treatments, in *Tolypothrix* and *Aulosira*, being more effective and statistically significant in the latter. The pigment accumulation in *Nostoc* was slightly and insignificantly promoted by all herbicide doses except at the highest concentration where a slight drop was noticed. The herbicide was most efficient at lower doses, in stimulating glucose absorption by either *Nostoc* and *Anabaena* up to 0.1 ppm thereabove, remarkable drop was maintained. It induced significant retardation in the sugar uptake by *Tolypothrix* and *Aulosira*. Such trend was furthered by increasing the herbicide concentration. Under all treatments of atrazine the total carbohydrate accumulation in all test algae was suppressed being more effective at the lowest concentration in *Tolypothrix* and *Aulosira* and of less significant effect in *Anabaena* and *Nostoc*. It may be concluded that the toxic effects of atrazine are partially due to its inhibitory effects on the synthesis of carbohydrates.

Shabana, E.F. (1987a) Use of batch assays to assess the toxicity of atrazine to some selected cyanobacteria: Influence of atrazine on the growth, pigmentation, and carbohydrate contents of *Aulosira fertilissima, Anabaena orizae, Nostoc muscorum* and *Tolypothrix tenuis. J. Basic Microbiol.* 27(2): 113–119. (NC)

Shabana, E.F. (1987b) Use of batch assays to assess the toxicity of atrazine to some selected cyanobacteria. II. Effect of atrazine on heterocyst frequency, nitrogen and phosphorus metabolism of four heterocystous cyanobacteria. *J. Basic Microbiol.* 27(4): 215–223.

Summary: Atrazine added in different doses to the culture media, augmented with glucose, of *Aulosira fertilissima, Tolypothrix tenuis, Anabaena oryzae* and *Nostoc muscorum* enhanced heterocyst frequency and efficiency of nitrogen fixation. Variations in the amounts of fixed nitrogen between the four test organisms may be attributed to differences in the levels of the high energy substance ATP, and also to various effects on the permeability barrier of cells. Although atrazine is a metabolic inhibitor, it enhanced particularly the nitrogen and phosphorus metabolism, leading to more amino-N and protein-N accumulation, yielding active synthesis of organic phosphorus, total soluble and insoluble phosphorus contents.

Shalan, S.N., Alaa El-Din, M.N., El-Sayed, M., Khadr, M.S., Shakr, M. (1982) Effect of herbicides on the rice yield inoculated with blue-green algae. Paper presented at the first OAU/STRC Inter-African Conference on Bio-fertilizers, Cairo (Egypt), March 22–26. (NC)

Shalan, S.N., Alaa El-Din, M.N., Hassan, M.E., Khadr, M.S. Shakr, M. (1984) Effect of herbicides on the rice yield inoculated with blue-green algae. Second Conference of the Agricultural Research Centre, Giza, Egypt, April 9–11. (NC)

Shankar, K.M., Varghese, T.J. (1981) Evaluation of potassium permanganate for control of *Microcystis* bloom. *Mysore J. Agric. Sci. 15: 150–153.*

Summary: Observations made on the phytotoxic effect of $KMnO_4$ on the bloom forming blue-green alga *Microcystis* sp., are reported. $KMnO_4$ was found to be effective in controlling *Microcystis* at a dosage of 8 ppm. The death of the alga was confirmed by microscopic observations. Bioassay experiments revealed that the above concentration was not lethal to carp fingerlings. However, zooplankton like rotifers and cladocerans could not withstand the dosage of 8 ppm of $KMnO_4$, whereas copepods were not affected. Observations on the addition of oxygen in $KMnO_4$ treated water were also made, and DO values between $KMnO_4$ and $CuSO_4$ treated waters were compared.

Sharma, V.K. (1984) Pesticide interaction with cyanobacterial nitrogen fixation and paddy yield in India. *Environ. Conserv.* 11(3): 265–267. (NS)

Notes: A short review with eight references.

Sharma, V.K., Gaur, Y.S. (1980) Growth, nitrogen and carbohydrate contents in nitrogen-fixing algal strains resistant to pesticides. Pages 47–50 in *Proceeding of the National Working of Algal Systems*. Indian Society of Biotechnology, IIT/ New Delhi 110016, India.

Summary: The effects of five combination of pesticides on paddy-field algae (*Nostoc* sp. and *Aulosira fertilissma*) under N_2-fixing conditions in the laboratory were studied. An increased growth was obtained in only one strain of each alga, but the percentage of total N decreased in all strains. However, relatively less decrease in percentage of total N was observed in strains of both algae resistant to PMA, MEMC, Lindane combination. Similarly, little decrease in percentage of carbohydrates was observed in resistant strains of *Nostoc* sp. and *Aulosira fertilissima*. Only fast growing pesticide resistant strains excreted more N in the culture filtrates in comparison to normal strains.

Notes: *In vitro* experiments on the effect of five combinations of PMA, MEMC, Lindane, and Phosvel on strains of *Nostoc* and *Aulosira* adapted to pesticides by repetitive subculturing in medium with pesticide. N content decreased in all strains but decrease was minimum in adapted strains. Fast growing pesticide resistant strains excreted more N than parent strains.

Sharma, V.K., Gaur, Y.S. (1981) Nitrogen fixation by pesticide-adapted strains of paddy field cyanophytes. *Intl. J. Ecol. Env. Sci.* 7: 117–122.

Summary: Tolerance limits of the N_2-fixing cyanophytes to certain paddy-field pesticides has been studied. The reduction in total nitrogen content of the pesticide-adapted strains has been ascribed to the inhibition of some stage(s) during the process of dinitrogen fixation or protein formatin or perhaps both.

Sharma, V.K., Gaur, Y.S. (1982) Interaction of paddy-crop pesticides with nitrogen-fixing cyanophytes. *Pesticides* 82: 5–6.

Summary: While it has been found that application of pesticides retard both growth and fixation of atmospheric nitrogen by paddy-field algae, their sensitivity to different pesticides vary considerably.

Shilo, M. (1965) Study on the isolation and control of blue-green algae from fish ponds. *Bamidgjeh* 17: 83. (NC)

Shivaprakasha, M.K., Shivappa Shetty, K. (1986) Effect of three common agricultural chemicals on growth and nitrogen fixation by blue-green algae. *J. Soil. Biol. Ecol.* 6: 16–23. (NC)

Shivaram, S., Shivappa Shetty, K. (1988) Studies on the effect of pesticides on the growth and nitrogen fixation by blue-green algae. *Mysore J. Agric. Sci.* 22: 222–225.

Summary: Six blue-green algal isolates viz. *Anabaena variabilis, Calothrix* sp., *Cylindrospermum musicola, Hapalosiphon welwitschii, Nostoc* sp. and *Scytonema hofmani* were tested for their growth and N_2 fixing ability under different concentrations of three pesticides viz. Rogor, Dithane M-45, and 2,4-D sodium salt in pure culture. The growth and N_2 fixation by all the six isolates were favoured at lower concentrations of the pesticides whereas higher concentrations gave an adverse effect.

Shtina, E.A. (1957a) Die Einwirkung des Herbizids 2,4-D auf die Bodenalgen. *Tr. Kirovsk Sel'choz Inst.* 12: 24. (NC)

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. (NS)

Notes: In Russian with no English summary.

Singh, A.L., Singh, P.K., Singh, P.L. (1988) Effects of different herbicides on the *Azolla* and blue-green algal biofertilization of rice. *J. Agric. Sci.* 111(3): 451–458.

Summary: Pre-emergence herbicides applied at field recommended doses, three days after transplanting (DAT) rice plants, inhibited growth and N_2-fixation of *Azolla pinnata* (Bangkok) and BGA (blue-green algae) inoculated 10 DAT. This inhibition was up to 15 DAT in *Azolla* and up to 20 DAT in BGA. Butachlor and oxadiazon resulted in higher toxicity to *Azolla* and BGA than benthiocarb and pendimethalin. The application of 0.5 kg/ha active ingredient of 2,4-DNa did not inhibit growth of *Azolla* but inhibited BGA growth. However, 2,4-DEE [2,4-D ethyl ester], a post-emergence herbicide, applied 30 DAT showed inhibitory effects on the growth and N_2-fixation of both *Azolla* and BGA. Inoculation of 2.0 t/ha of fresh *Azolla* 10 DAT produced maximum biomass within 20–25 days of herbicide treatments, depending upon the season. The inoculation of 10 kg/ha of a dry mixture of BGA 10 DAT could produce the maximum biomass 60 and 80 DAT in control and herbicide treated plots, respectively. The biomass and nitrogen produced by *Azolla* recorded at maximum mat formation were similar in both herbicide treated and untreated plots, but in BGA these were higher in controls than those of herbicide treated plots. The use of *Azolla* and BGA biofertilizers along with herbicides increased the grain and straw yields,

and panicle number and nitrogen uptake, by rice over no *Azolla* or BGA treatments. The *Azolla* and BGA treatments even without weeding increased rice yield up to that of herbicide and biofertilizer treatments.

Singh, D.P., Singh, P.K. (1988) Effects of phosphorus and carbofuran on the growth and nitrogen fixation of *Azolla pinnata* and the yield of rice. *Expl. Agric.* 24: 183–189.

Summary: The effects of phosphorus fertilizer and the insecticide carbofuran on the growth and N_2-fixation of *Azolla pinnata* and on the growth, grain yield and nitrogen uptake of intercropped rice were examined in a wet and a dry season. Treatment with phosphorus or carbofuran increased the biomass of *Azolla* and the amount of N_2 fixed (nitrogen yield) in both seasons, but the response was much better in the dry season. *Azolla* inoculation at 1.0 t/ha resulted in a greater biomass and nitrogen yield than inoculation at 0.5 t/ha. In the dry season, a combination of phosphorus and carbofuran enhanced the growth and N_2-fixation of *Azolla* more than either treatment alone. Carbofuran treatment slowed the rate of *Azolla* decomposition, particularly in the dry season. The plant height, leaf area index and dry matter production of rice at flowering time were increased in the plots treated with phosphorus or carbofuran in the wet season and these treatments increased rice grain yield and nitrogen uptake in both the wet and dry seasons.

Singh, D.T., Nirmala, K., Modi, D.R., Katiyar, S., Singh, N.H. (1987) Genetic transfer of herbicide resistance gene(s) from *Gloeocapsa* sp. to *Nostoc muscorum*. *Mol. Gen. Genet.* 208(3): 436–438.

Summary: An aerobic diazotrophic *Gloeocapsa* strain contained genes conferring resistance to the growth toxic effects of ricefield herbicides Machete and Basalin. The results of genetic crosses and of DNA-mediated genetic transformation experiments both suggested the absence of a heterospecific barrier for the transfer of herbicide resistance genes from a *Gloeocapsa* strain to *Nostoc muscorum* and their stable expression and maintenance in the latter. These findings will have considerable implications in cyanobacterial biofertilizer technology.

Singh, H.N., Singh, H.R., Vaishampayan, Y. (1979) Toxic and mutagenic action of the herbicide alachlor (Lasso) on various strains of the N_2-fixing blue-green alga *Nostoc muscorum* and characterization of the herbicide-induced mutants resistant to methylamine and L-methionine-DL O sulfoximine. *Environ. Expt. Bot.* 19(1): 5–12.

Summary: Alachlor (lasso), like butachlor (machete) shows mutagenic properties when tested in *Nostoc muscorum* systems. The mutagenicity of the two herbicides seems considerably higher than that of MNNG (N-methyl-N'-nitro-N-nitroso guanidine). A dose of alachlor considerably higher than that of butachlor is needed to obtain a comparable level of growth inhibition and mutagenesis, thus suggesting that butachlor is the more efficient mutagen. Methylamine-resistant (MA-R) and L-methionine-DL-sulfoximine-resistant (MSO-R) mutants have been obtained spontaneously or following mutagenic treatment with either herbicide. MA-R strains appear to metabolize methylamine as a nitrogen source. MSO-R strains do not form heterocysts in ON^{-3} or NH^{+4} medium containing or lacking MSO; the parent *N. muscorum* does not form heterocysts in NO^{-3} or NH^{+4} medium lacking MSO but does form them in either nitrogen medium containing MSO.

Singh, H.N., Vaishampayan, A. (1978) Biological effects of rice-field herbicide Machete on various strains of the nitrogen-fixing blue-green alga *Nostoc muscorum*. *Environ. Exper. Bot.* 18(2): 87–94.

Summary: The pre-emergence ricefield herbicide Machete (2-chloro-2', 6'-diethyl-N (butoxy methyl) acetanilide), is apparently toxic and lytic to parental, het^+ nif^-_{11}, and Em-R het^- nif^-_2 strains of *Nostoc muscorum*. The intensity of the biological effects induced by the herbicide increases with the growth-promoting efficiency of various inorganic nitrogen sources. The herbicide has no effect on heterocyst differentiation, and induced biological perturbations are not reversed by glucose. Machete appears to be strong mutagen as 5–6 percent of the het^+ nif^-_{11} and Em-R het^- nif^-_2 are prototrophic revertants.

Singh, L.J., Tiwari, D.N. (1988) Some important parameters in the evaluation of herbicide toxicity in diazotrophic cyanobacteria. *J. Appl. Bacteriol.* 64(5): 365–370.

Summary: The effect of different inocula sizes on the toxicity of the herbicides machete, basalin and propalin was tested. The inocula sizes gave differential response pattern towards a particular herbicide dose and, as such, the employment of a specific dose inoculum response is suggested. Furthermore, *Gloeocapsa* sp. showed remarkable herbicide resistance potential while *Nostoc muscorum* was quite susceptible to all the herbicides.

Singh, L.J., Tiwari, D.N., Singh, H.N. (1986) Evidence for genetic control of herbicide resistance in a ricefield isolate of *Gloeocapsa* sp. capable of aerobic diazotrophy under photoautotrophic conditions. *J. Gen. Appl. Microbiol.* 32(2): 81–88.

Summary: The ricefield isolate of *Gloeocapsa* sp. grew aerobically at the expense of N_2 as a nitrogen source and showed DCMU-sensitive aerobic nitrogenase activity under photoautotrophic conditions. The two pre-emergence ricefield herbicides Machete and Basalin strongly inhibited growth, photosynthesis, respiration, and nitrogenase activity in *Nostoc muscorum*, in a concentration hardly inhibitory to these processes in *Gloeocapsa* sp. Ethidium bromide treatment of *Gloeocapsa* sp. resistant to growth inhibition by Machete and Basalin resulted in nonreversible loss of both herbicide resistant phenotypes (Macr and Basr) without affecting aerobic diazotrophy. The nonreversible Macs Bass strain resulting from Ethidium bromide treatment of Macr Basr *Gloeocapsa* strain stopped growth, N_2-fixation, and photosynthetic O_2 evolution when inoculated in growth medium containing 10 or 20 g/ml of Machete, Basalin, or both. These findings suggest that the ricefield isolate of *Gloeocapsa* sp. is a naturally occurring Machete and Basalin resistant strain dependant on photosynthesis for aerobic diazotrophy and that the genes for the two herbicide-resistant phenotypes are possibly plasmid-borne. The present findings will have a significant bearing on the future of cyanobacterial biotechnology in agriculture.

Singh, P.K. (1973) Effects of pesticides on blue-green algae. *Arch. Mikrobiol.* 89: 317–320.

Summary: Effect of pesticides, i.e., Benzene Hexachloride, Lindane, Diazinon and Endrin that are often used in India was observed on N_2-fixing blue-green algae *Cylindropermum* sp., *Aulosira fertilissima* and aerobically non-N_2-fixing blue-green alga *Plectonema boryanum* strain 594. These algae were sensitive for BHC in comparison to other pesticides. *A. fertilissima* and *P. boryanum* were more resistant than *Cylindropermum* sp.

Singh, P.K. (1974) Algicidal effect of 2,4-dichlorophenoxy acetic acid on blue-green alga *Cylindrospermum* sp. *Arch. Microbiol.* 97: 69–72.

Summary: The effect of the herbicide 2,4-Dichlorophenoxy acetic acid generally used in agriculture was studied on the N_2 fixing blue-green alga *Cylindrospermum* sp. The alga could tolerate up to 150 g per ml in liquid culture and 100 g per ml on agar plates without any inhibitory effect on growth and survival. The maximum tolerance was up to 800 g per ml and higher concentrations were lethal.

Singh, R.K., Singh, B., Singh, H.N. (1983) Inhibition of photosystem II of the nitrogen-fixing blue-green alga *Nostoc linckia* by the ricefield herbicide benthiocarb. *(Eng) Z. Allg. Mikrobiol.* 23(7): 435–441.

Summary: Effects of ricefield herbicide benthiocarb (S-(4-chlorobenzyl)-N,N-diethyl thioclarbamate) was studied on the N_2-fixing blue-green alga *N. linckia*. The herbicide caused inhibition of growth and heterocyst formation, an increase in intensity of photoacoustic signals and a four-fold reduction in oxygen evolution but did not affect dark O_2-uptake. The inhibition of growth and heterocyst formation was relieved by 500 g/ml glucose. A Het^- Nif^- mutant of *N. muscorum* failed to show an increase in reversion frequency after treatment with 10 g/ml benthiocarb for one hour.

Singh, R.P., Singh, R.K., Tiwari, D.N. (1986) Effect of herbicides on the composition of cyanobacteria in transplanted rice. *Plant Prot.* Q 1(3): 101–102.

Summary: The effect of butachlor (1.5 kg ai/ha), thiobencarb (1.5 kg ai/ha) and 2,4-D (1.5 kg ai/ha) on the presence of N_2-fixing photosynthetic procaryotic cyanobacteria was studied in rice bays during the summer monsoon at Varanasi, India. Herbicides at the recommended rate had little effect on the percentage of *Phormidium, Microcystic* and *Microcoleus* sp. present in the algal biomass. All herbicides increased the proportion of the blue-green algae such as *Nostoc*, while only propanil reduced the proportion of *Anabaena* in the algae population. In general, the recommended rates of herbicide did not result in major changes in the composition of the algal population.

Notes: Field experiment showing that, in general, the recommended doses of herbicides did not resulted in major changes in the composition of the algal population. However all herbicides increased the proportion of *Nostoc* sp.

Singh, V.P., Singh, B.D., Dhar, B., Singh, R.M., Srivastava, J.S., Singh, R.B. (1978) Effect of herbicide, alachlor on growth and nitrogen fixation in cyanobacteria and rhizobia. *Indian J. Exp. Biol.* 16(12): 1325–1327.

Summary: Rhizobium strain SU391 was more resistant to alachlor than other strains. Two nitrogen fixing, filamentous species of cyanobacteria were more sensitive than a unicellular non-fixing species. Rhizobia tolerated four to five times higher concentrations than the cyanobacteria. Heterocysts in *Anabaena doliolum* were spaced more widely when grown in 5–40 µg/ml alachlor. Nitrogen fixation in *A. doliolum* and *Nostoc muscorum* was adversely affected only at relatively higher concentrations (above 20 µg/ml).

Singh, V.P., Singh, R.B., Singh, B.D., Singh, R.M., Dhar, B., Srivastava, J.S. (1978) Toxicity of butachlor to nitrogen-fixing microorganisms. *Beitr. Biol. Pflanz.* 54(2): 227–238.

Summary: Toxicity of the herbicide butachlor [2-chloro-2,6-diethyl-N (butoxymethyl) acetanilide] was determined in vitro on seven strains of *Rhizobium* sp. and three species of blue-green algae. *R. leguminosarum* strains (SU 391, 1045 and P 5) showed a more resistant growth pattern than other stains, 32H1, CB756, M7 (cowpea *Rhizobium*) and CB1809 (*R. japonicum*). The unicellular non-N-fixing blue-green alga, *Aphanothece stagnina*, was more resistant than the two filamentous N-fixing species. The *Rhizobium* tolerated 10- to 50-fold higher concentrations of butachlor (100 μg/ml) than the blue-green algae (2 or 10 μg/ml). Low concentrations of butachlor (0.5–2.0 μg/ml) significantly increased heterocyst spacing in *Anabaena doliolum*. The N-fixing ability of *A. doliolum* and *Nostoc muscorum* in 1 μg/ml butachlor was comparable to the control, but at the higher concentrations (2–8 μg/ml) it was adversely affected, especially in the case of *A. doliolum*.

Sinha, P.K., Pal, S., Trial, S.B. (1986) An effective molluscicide for grazer snails of blue green algae. *Pesticides* 20(2): 44–45.

Summary: The snails of irrigation water were found grazing severely blue green algae of paddy fields. Available insecticides viz carbofuran, phorate, carbaryl, endosulfan, diazinon, chlorpyrifos, and thiodicarb were tried in the laboratory to control their damage. Thrice replicated five concentrations i.e. 100, 50, 10, 5 and 1 ppm of above insecticides were tried and two recordings of mortality at four and 24 hours were made after the treatment. Thiodicarb proved cent percent effective at 5 ppm and even at 1 ppm after four and 24 hours respectively. It also proved safer to BGA and local fishes of paddy fields at 1 ppm.

Smith, R.J., Jr., Flinchum, W.T., Seaman, D.E. (1977) *Weed control in U. S. rice production*. Agriculture Handbook No. 497, USDA, Washington DC. 78 pp.

Notes: Includes tables summarizing the control of common ricefield weeds by cultural practices and pesticides.

Smith, R.J., Jr., Viste, K.L., Shaw, W.C. (1959) Progress in weed control in rice production in the United States. *Int. Rice Comm. Newsl.* 8(3): 1–6.

Summary: The significant results of five years of investigations on the control of weeds in the rice-producing areas of Arkansas and California have been discussed. No attempt has been made to present all the technical results of these investigations. A method of controlling weed grasses in the south-eastern rice-producing area involving the use of CIPC in combination with several cultural management practices has been developed. The combination herbicide-cultural

practice was used effectively to control barnyard grass and other weed grasses on more than 5,000 acres of commercially grown rice in 1959. In the western rice-producing area, CIPC and EPTC, in combination with various cultural practices, have shown experimental promise for the control of barnyard grass and other weed grasses; but these herbicides are not presently suggested for commercial use. Intensive fundamental investigations have been conducted to develop basic information on the use of 2,4-D, MCPA, 2,4,5-T, and silvex for the most effective control of a wide range of broadleaved weeds and sedges with minimum risk of injury to rice. It is estimated that over 40 percent of the total rice crop in the United States is treated annually with phenoxy-type herbicides for the control of weeds. Basic and applied studies are being continued to improve current weed-control practices and to develop new herbicides and new improved chemical-cultural methods of controlling weeds in rice.

Srinivasan, S. (1981a) Control of daphnids in blue-green algae multiplication plots. (Eng) *Int. Rice Res. Newsl.* 6(3): 16. (NS)

Notes: Carbofuran, Carbaryl, BHC, Quinalphos, Mephosfolan, Phorate, and Diazinon applied at normal rate (0.6–1.3 kg ai/ha) significantly increased BGA growth in plots used for the production of soil-based inoculum.

Srinivasan, S. (1981b) Screening blue-green algae types tolerant of daphnids in paddy fields. (Eng) *Int. Rice Res. Newsl.* 6(2): 18–19. (NS)

Notes: Field experiment on BGA production in inoculum multiplication plots. Refers to grazer control by carbofuran and Ekalux.

Srinivasan, S., Ponnuswami, V. (1978) Influence of weedicides on blue-green algae. *Aduthurai Rep.* 2(11): 136. (NS)

Notes: Field experiment on BGA production in inoculum multiplication plots. Among nine formulations tested at the recommended dose, three significantly decreased inoculum production by an average 36 percent. When the dose was doubled, four formulations significantly reduced algal production.

Stratton, G.W. (1984) Effects of the herbicide atrazine and its degradation products, alone and in combination, on phototrophic microorganisms. *Arch. Environ. Contam. Toxicol.* 13(1): 35–42.

Summary: Toxic effects of the herbicide atrazine and four of its degradation products were determined for growth, photosynthesis and acetylene-reducing ability of two species of green algae [*Chlorella pyrenoidosa, Scenedesmus quadricauda*] and three species of cyanobacteria [*Anabaena inaequalis, A.*

cylindrica, A. variabilis]. Atrazine was significantly more toxic than its degradation products towards the test criteria, yielding EC50 values ranging from 0.1–0.5 ppm (g/ml) for photosynthesis and 0.3–5.0 ppm for growth. De-ethylated atrazine was the next most toxic with EC50 values of 0.7–4.8, and 1.0–8.5 ppm for photosynthesis and growth, respectively. With deisopropylated atrazine the EC50 values for the same physiological functions ranged from 3.6–9.3 and 2.5 to > 10 ppm, respectively. Hydroxy- and diamino-atrazine were nontoxic towards most cultures. Acetylene reduction with cyanobacteria was insensitive to all test compounds, except for atrazine, which had an EC50 of 55 ± 15 ppm towards *A. inaequalis*. Combinations of atrazine and its monodealkylated products were tested with *A. inaequalis* and yielded synergistic, antagonistic and additive interaction responses, depending upon the actual test system employed.

Stratton, G.W., Burrell, R.E., Lynn Kurp, M., Corke, C.T. (1980) Interactions between the solvent acetone and the pyrethroid insecticide permethrin on activities of the blue-green alga *Anabaena*. *Bull. Environm. Contam. Toxicol.* 24: 562–569. (NS)

Stratton, G., Corke, C.T. (1981) Effect of acetone on the toxicity of atrazine towards photosynthesis in *Anabaena*. *J. Environ. Sci. Health Part B Pestic. Food Contam. Agric. Wastes* 16(1): 21–34.

Summary: The effect of acetone on the toxicity of atrazine towards photosynthesis in the blue-green algae *Anabaena inaequalis, A. variabilis* and *A. cylindrica* was investigated. The order of sensitivity to atrazine was *A. inaequalis* > *A. variabilis* > *A. cylindrica*. Acetone and atrazine interacted additively, antagonistically, and synergistically, depending upon the concentrations of acetone and atrazine used. The EC50 of atrazine towards photosynthesis was dependent upon the type of solvent-pesticide interaction.

Stratton, G.W., Corke, C.T. (1982) Toxicity of insecticide permethrin and some degradation products towards algae and cyanobacteria. *Environ. Pollut. Ser. A Ecol. Biol.* 29(1): 71–80. (NC)

Subba-Rao, R.V., Alexander, M. (1980) Effect of DDT metabolites on soil respiration and on an aquatic alga. *Bull. Environ. Contam. Toxicol.* 25: 215–220. (NS)

Notes: DDT and DDT metabolites (DDE, DDD, DDA, PCPA, BHE, DCBHE, DDM, DBH, DPB) at 1 and 10 ppm had: no marked effect on the chlorophyll content and biomass of *Chlorella vulgaris* measured as the average values and concentration in eight and 13 days cultures; no marked effect on soil respiration measured for two to three days after pesticide application with classical respirometric techniques on 0.5 g of soil.

Subramanian, G. (1982) The effect of pesticides on nitrogen fixation and ammonia excretion by *Anabaena*. Pages 567–587 in *Proceeding of the National Symposium on Biological Nitrogen Fixation*, New Delhi. (NS)

Notes: Laboratory study of the effect of BHC, Carbaryl, Ekalux, and Dithane on the growth, ARA, and ammonium excretion by four *Anabaena* sp.

Subramanian, G., Shanmugasundaram, S. (1986) Influence of the herbicide 2–4-D on nitrogen fixation and ammonia excretion by the cyanobacterium *Anabaena*. *Proc. Ind. Nat. Sci. Acad. Part B Biol. Sci.* 52(2): 308–312.

Summary: 2,4-D (2,4-Dichlorophenoxyacetic acid) at concentrations of 1–100 ppm did not have any adverse effect on six strains of *Anabaena*. The growth was stimulated in some strains. While in some strains, nitrogenase activity was considerably stimulated, in others, the activity decreased with increasing concentrations. The excretion of ammonia under the influence of 2,4-D varied with the strains and showed no correlation to nitrogenase activity.

Synder, C.E., Sheridan, R.P. (1974) Toxicity of the pesticide Zectran on photosynthesis, respiration and growth in four algae. *J. Phycol.* 10: 137. (NC)

Takamura, K. Yasuno, M. (1986) Effects of pesticide applications on chironomids, ostracods and other benthic organisms in ricefields. *Res. Rep. Natl. Inst. Environ. Stud. Japan* 99: 81–90.

Summary: Benthic organisms were surveyed in ricefields treated with pesticides differently during late May-August, 1983; no pesticide, herbicide only, and herbicide + insecticide + fungicide. Total count of benthic bacteria decreased from the other of 1,010 cells/ml to the order of 109 cells/ml after the simultaneous application of insecticide and herbicide. Chironomids and ostracods appeared in large numbers. They increased markedly in the pesticide-treated fields. Larval populations of odonates and dytiscids which prey on chironomid larvae and ostracods, were depressed with pesticides. This result allowed the marked increase in the populations of chironomids of their numbers each other in some degree. Benthic algae decreased with applications of herbicide and did not increase markedly in the pesticide-treated fields. The latter cases could also be ascribed to heavy grazing by chironomids and ostracods.

Notes: Field survey showing a decrease from 10^{10}/ml to 10^{9}/ml of the total benthic bacteria in herbicide + insecticide treated fields as well as the development of large populations of chironomids and ostracods. Simultaneously, the number of natural predators of chironomids and ostracods decreased. Benthic algae decreased in herbicide treated plots and did not increase in insecticide treated plots probably because of grazing by ostracods.

Takamura, K., Yasuno, M. (1986) Effects of pesticide application on chironomid larvae and ostracods in ricefields. *Appl. Ent. Zool.* 21(3): 370–376.

Summary: Benthic macroinvertebrates were surveyed in ricefields in which three pesticide applications were adopted; no pesticide, herbicide only, and herbicide + insecticide + fungicide. Abundant taxa were chironomid and ostracod. The populations of these animals fluctuated widely in the pesticide-treated ricefields. Larval populations of odonates and dytiscids which prey on chironomid larvae and ostracods, were depressed according as various pesticides were applied. The low density of predators presumably allowed the large increase in the populations of chironomids and ostracods. However, competition between chironomids and ostracods, as well as the direct toxic effect of pesticides, may have suppressed the increase of their numbers in some degree. Benthic algae decreased with most applications of herbicide. The algae showed a slight increase probably due to heavy grazing by chironomids and ostracods and to herbicide toxicity in the pesticide-treated fields.

Tandon, R.S., Lal, R., Narayana, Rao, VVS (1988) Interaction of endosulfan and malathion with blue-green algae *Anabaena* and *Aulosira fertilissima*. *Environ. Pollut.* 52(1): 1–10.

Summary: The growth of *Anabaena* and *Aulosira fertilissima* was adversely affected by endosulfan even at 1 µg/ml. The inhibition was significantly above 50 percent at 20 µg/ml throughout the incubation. *Anabaena* survived up to 500 µg/ml of malathion, but was completely bleached in the presence of 50 µg/ml of endosulfan. *Aulosira* was more sensitive to malathion than *Anabaena* and recovered to control levels only at 10 µg/ml. The morphology and heterocyst frequency were not altered in *Anabaena*. *Aulosira* cultures were dull brown in colour at 20 µg/ml of endosulfan with the filaments clumping, instead of the usual mat formation. Both malathion and endosulfan considerably lowered ^{14}C uptake and nitrogenase activities in *Aulosira*. Nitrogen fixation was unaffected in *Anabaena* as the amounts of ethylene produced were equal to, or above, control levels. The impact of these insecticides on photosynthesis in *Anabaena* was only slight.

Tarar, J.L., Shewale, T.H. (1984) Studies on the effects of some fungicides on soil algae of paddy fields. *Phykos* 23(1–2): 191–201. (NC)

Theivendirarajah, K., Jeyaseelan, K. (1981) Effect of herbicide, isopropyl ester of 2,4-dichlorophenoxyacetic acid (2,4-Dipe), on blue-green algae. *Ceylon J. Sci.* 14(1/2): 10–14.

Summary: The effect of the hormonal herbicide Isopropyl ester of 2,4-Dichloro phenoxyacetic acid (2,4-DIFE) on the growth of two N_2-fixing blue-green algae *Nostoc carneum* and *Anabaena* sp. and the non-N_2-fixing blue-green alga *Anacystic nidulans* was studied. The rate of growth and the final cell number of these algae were not affected by this weedicide even at a concentration that is approximately 15 times more than the concentration used in paddy soils.

Tirol, A.C., Santiago, S.T., Iwao Watanabe, I. (1981) Effect of the insecticide, carbofuran, on microbial activities in flooded soil. *J. Pestic. Sci.* (*Nihon Noyakugaku Kaishi*) 6(1): 83–90.

Summary: The effects of carbofuran in some soil microbial activities (N mineralization, nitrification, N-fixation by blue-green algae, and urea hydrolysis) were investigated in the laboratory and the greenhouse. The addition of 10 μg ai [active ingredient] carbofuran/g dried soil had no inhibitory effect on the mineralization of native soil N. 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 the addition of 6 kg ai carbofuran/ha to the floodwater. Subsequently, a marked increase 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 apparently was faster in dry land than in flooded soil. The addition of 50 ppm ai carbofuran did not affect the rate of urea hydrolysis.

Tiwari, D.N., Pandey, A.K. (1981) 2,4-D-resistant mutant strains of *Anacystis nidulans* and filament formation. *Indian J. Exp. Biol.* 19(10): 988–990.

Summary: Spontaneous mutants of the unicellular blue-green alga, *A. nidulans*, resistant to 2,4-D were isolated; the mutant frequencies ranged $2 - 8 \times 10^6$. The concentration of the herbicide (2 mg/ml), lethal to the parent clone, permitted the growth of presumptive herbicide-resistant mutants in the form of filaments. These mutants did not show filamentous growth in herbicide-free medium. Several successive generations in basal herbicide-free medium and retransfer of

these mutants into herbicide supplemented medium resulted in 100 percent survival accompanying filamentous growth. None of the 2,4-D concentrations permitting the growth of parent alga caused filamentous growth of the mutant strains. Cellular abnormalities in mutants at higher concentrations of 2,4-D and the possible involvement of this chemical at the level of cell division are discussed.

Tiwari, D.N., Pandey, A.K., Misra, A.K. (1984) Toxicity of 2,4-D on growth and nitrogen fixation of blue-green alga *Anabaena cylindrica*. *Pesticides* (Bombay) 18(11): 16–18.

Summary: Toxicity of 2,4-D on growth characteristics of nitrogen-fixing blue-green alga, *A. cylindrica*, was observed under various sources of inorganic N. The alga exhibited a higher growth rate and survival in the presence of 2,4-D in nitrate medium as compared to N free and ammonia medium. With 100 μg/ml of 2,4-D in the medium, there was slightly stimulated growth of the alga. A slight increase in the frequency of heterocyst was observed in 100 μg/ml of 2,4-D in N free medium but higher concentrations markedly reduced the frequency. Total nitrogen fixation by the alga was inhibited by the higher concentrations of 2,4-D; at 100 μg/ml, nitrogen fixation was higher than control.

Tiwari, D.N., Pandey, A.K., Mishra, A.K., Srivastava, V. (1982) Role of 2,4-D on growth and macromolecular synthesis in cyanobacterium *Anabaena cylindrica*. *Indian J. Bot.* 5(2): 111–114.

Summary: Effect of 2,4-D on growth and macromolecular synthesis of a N_2 fixing blue-green alga, *Anabaena cylindrica* have been observed. The alga exhibited a higher growth rate with 100 μg/ml 2,4-D supplemented medium than control. Total protein, carbohydrate, phycocyanine and N_2 fixed by the alga was slightly enhanced by 100 μg/ml 2,4-D and RNA (up to 500 μg/ml) while DNA and chlorophyll a synthesis was not supported. Higher concentrations of 2,4-D inhibited growth, N_2 fixation and macromolecular synthesis.

Tiwari, D.N., Pandey, A.K., Pandey, A.K. (1979) Toxicity of malathion, (S-(1,2-Di(Ethoxy carbonyl)ethyl) dimethyl phosphoro-thiothionate), on growth and nitrogen fixation of cyanobacterium *Nostoc calcicola*. *J. Sci. Res. Banaras Hindu Univ.* 30: 92. (NC)

Tomaselli, L., Giovannetti, L., Materassi, R. (1987) Effect of simazine on nitrogen-fixing cyanobacteria in soil. *Ann. Microbiol. Enzimol.* 37(2): 183–192.

Summary: The effect of the herbicide simazide on the algal and cyanobacterial population of a cultivated soil was studied. The results obtained showed that heterocystous, nonheterocystous cyanobacteria and microalgae were differently affected by the repeated use of simazine (4 kg/ha), the first being more severely affected. Moreover the herbicide produced a strong reduction in the species diversity. This reduction was very evident in the case of heterocystous cyanobacteria.

Torres, A.M.R., O'Flaherty, L.M. (1976) Influence of pesticides on *Chlorella, Chlorococcum, Stigeoclonium* (Chlorophyceae) and *Oscillatoria* (Cyanophyceae). *Phycologia* 15: 25. (NC)

Tubea, B., Hawxby, K., Mehta, R. (1981) The effects of nutrient, pH and herbicide levels on algal growth. *Hydrobiologia* 79(3): 221–228.

Summary: Growth inhibition of algae [*Chlorella pyrenoidosa* and *Lyngbya birgei*] increased as herbicide concentrations increased, particularly with prometryn and fluometuron. Picloram had no effect on algal growth and dinoseb inhibited only *L. birgei*. There were no differences in growth rate of algae treated with different levels of K or P. High levels of Ca or Mg increased growth rate of the algae tested. High levels of N or pH increased growth rates except when combined with prometryn or fluometuron.

Tucker, C.S., Lloyd, S.W. (1987) Evaluation of potassium ricinoleate as a selective blue-green algicide in channel catfish ponds. *Aquaculture* 65(2): 141–148.

Summary: The effectiveness of potassium ricinoleate as a selective blue-green algicide was investigated in experimental channel catfish, *Ictalurus punctatus*, culture ponds. Five ponds were treated with 0.8 mg/l potassium ricinoleate three times per week from May through October and five ponds served as controls. Treatment did not affect concentrations of chlorophyll-a, total and un-ionized ammonia-nitrogen, or dissolved oxygen; nor did it affect average hours of supplemental aeration or net fish production. The mean nitrite-nitrogen concentration in control ponds was higher ($P < 0.05$) than that in treated ponds, but concentrations of nitrite never reached levels considered detrimental to the health of the fish. Treatment did not reduce the incidence or percentage of blue-green algae in phytoplankton communities and did not prevent severe episodes of off-flavor in fish from treated ponds.

Vaishampayan, A. (1984a) Biological effects of a herbicide on a nitrogen-fixing cyanobacteria (blue-green alga): an attempt for introducing herbicide-resistance. *New Phytol.* 96(1): 7–11.

Summary: The herbicide monuron (3-(4-chloropheny)-1,1-dimethylurea) inhibits growth and heterocyst formation in the N_2-fixing cynobacterium *Nostoc muscorum*. These inhibitory effects are glucose-reversible in both N_2 (nitrogen-fee) and NO_3^- media. A spontaneous mutant of this cyanobacterium, resistant to a dose of monuron normally applied to the ricefields of North India, has been isolated and preliminarily characterized as having no requirement for an organic carbon source for its normal physiology under monuron-treated conditions. The behavior of the mutant has been tentatively explained as resulting from a permeation mutation preventing monuron entry into *N. muscorum*.

Vaishampayan, A. (1984b) Powerful mutagenicity of a bipyridylium herbicide in a nitrogen-fixing blue-green alga *Nostoc muscorum*. *Mutat. Res.* 138(1): 39–46.

Summary: The herbicide, paraquat (1,1'-dimethyl-4,4'-bipyridylium ion), was toxic and lytic to *N. muscorum* in N_2 (at the expense of elemental N, i.e., unsupplemented with any combined N source) and NO_3^- media, without any apparent inhibitory or stimulatory effect on its N_2 fixing apparatus, i.e., heterocyst formation. At a dose of paraquat resulting in 20, 50 and 75 percent survival, induction of reverse mutations (from $het^- nif^-$ auxotrophy to $het^+ nif^+$ prototrophy), forward mutations (for streptomycin [St]-resistance) and auxotrophic mutations (C-auxotrophy through methylamine [MA]-resistance) were observed with frequencies comparable to those obtained through induction with the well known mutagen MNNG (N-methyl-N'-nitro-N-nitrosoguanidine).

Vaishampayan, A. (1984c) Studies on diuron uptake in a blue-green alga *Nostoc muscorum*. *J. Exp. Bot.* 35(155): 897–904.

Summary: A mutant of *Nostoc muscorum* that is resistant to 3-(3.4-dichlorophenyl)-1,1-dimethylurea (diuron) has been selected. This mutant may lack the step in photosynthesis that is affected by diron (DCMU), but it can also use DCMU as a source of carbon and nitrogen. Another mutant of this organism resistant to L-methionine-DL-sulphoximine (MSO), that was isolated previously, also shows some cross resistance to DCMU.

Vaishampayan, A. (1985a) Biological effects on the ricefield herbicide monuron on a N_2-fixing cyanobacterium *Nostoc muscorum*. *Microbios Lett.* 28: 105–111.

Summary: The herbicide monuron (3-(4-chlorophenyl)-1,1-dimethylureal has been found to be an inhibitors of growth and heterocyst differentiation in the N_2-fixing cyanobacterium *Nostoc muscorum*. The inhibitory effects of monuron have been shown to be at the level of photosynthetic assimilation of inorganic

carbon, since these are reversible on supplementation with a readily assimilable carbon source like glucose, sucrose or sodium acetate.

Vaishampayan, A. (1985b) Mutagenic activity of alachlor, butachlor and carbaryl to a nitrogen-fixing cyanobacterium *Nostoc muscorum*. *J. Agric. Sci.* 104(3): 571–576.

Summary: Alachlor, butachlor and carbaryl were highly toxic to the N_2-fixing cyanobacterium *Nostoc muscorum*, when grown on solid minimal (nitrogen-free) medium. At pesticides doses allowing about 20, 50, and 60 percent survival of the organism, various mutations were obtained in *N. muscorum*, reverse mutation from het$^-$ nif$^-$ and het$^-$ nif$^-$ auxotrophy to het$^+$ nif$^+$ prototrophy, forward mutation for resistance to 0.37 mM L-methionine-DL-sulfoximine, and auxotrophic mutation for the achievement of carbon-auxotrophy through 5 mM methylamine-resistance. The toxic and mutagenic effects of the three pesticides were similar to those of the well known mutagen MNNG.

Notes: Experiments *in vitro* with *Nostoc muscorum*. Five ppm Alachlor reduced growth by 10 percent only, 110 ppm reduced growth by 50 percent. One ppm Butachlor reduced growth by 6 percent only, 10 ppm reduced it by 50 percent, and 80 ppm caused a complete inhibition. Two ppm Carbaryl reduced growth by 10 percent, 20 ppm reduced it by 50 percent, 150 ppm reduced it by 80 percent.

Vaishampayan, A. (1985c) Mutagenicity of a bipyridylium herbicide in a nitrogen-fixing cyanobacterium, *Nostoc muscorum*. *Environ. Int.* 10(4): 285–290.

Summary: The herbicide diquat (1,1'-ethylene-2,2'-bipyridylium ion) is toxic and lytic to *Nostoc muscorum*. A reverse mutation (from het$^-$ nif$^-$ auxotrophy to het$^+$ nif$^+$ prototrophy), a forward mutation (for streptomycin [St]-resistance), and an auxotrophic mutation (carbon-auxotrophy through methylamine [MA]-resistance) were obtained with a dose of diquat permitting ~ 20 and 50 percent survival. Similar mutation frequencies were obtained through induction with MNGG (N- methyl-N" -nitro-N-nitrosuguanidine).

Vaishampayan, A. (1985d) Mutagenicity of bipyridylium salts in a nitrogen-fixing cyanobacterium. *Microbios Lett.* 43(172): 53–65.

Summary: The bipyridylium herbicides diquat (1,1'-= ethylene-2,2'-bipyridylium ion) and paraquat (1,1'-dimethyl-4,4'-bipyridylium ion) are growth inhibitory to the N_2-fixing cyanobacterium *Nostoc muscorum* in N_2 (nitrogen-free), No_3^-, No_2^- ad NH_4^+ media. These herbicides have no apparent inhibitory effect on the heterocyst forming capacity of the organism. With a dose of either herbicide

resulting in ~ 20 and 50 percent survival of *N. muscorum*, respectively, various mutations were obtained. These include reverse mutation (reversion of het^+ nif^- and het^- nif^- auxotrophic markers to het^+ nif^+ prototrophy); forward mutation (for resistance to 1 ppm streptomycin and 2.5 ppm erythromycin); auxotrophic mutation (for the achievement of carbon-auxotrophy through methylamine-resistance). The toxic and mutagenic effects of these herbicides were compared with those of the well known mutagen N-methyl-N'-nitro-N-nitrosuguanidine and found to be stronger than the latter in each case.

Vaishampayan, A., Prasad, A.B. (1982) Blitox-resistant mutants of the N_2-fixing blue-green algae *Nostoc linkia* and *Nostoc muscorum*. *Environ. Expt. Bot.* 22(4): 427. (NC)

Vaishampayan, A., Singh, H.R., Singh, H.N. (1978) Biological effects of ricefield herbicide "Stam f-34" on various strains of the nitrogen-fixing blue-green alga *Nostoc muscorum*. *Biochem. Physiol. Pflanz.* 173(5): 410–419.

Summary: The post-emergence ricefield herbicide Stam f-34 is inhibitory to growth and heterocyst differentiation in the heterocystous N_2-fixing parent and heterocystous non-N_2-fixing (het hif_{11}^-) mutant strains of the blue-green alga *Nostoc muscorum* G. Similar effect is exerted by 3-(3,4-dichlorophenyl)-1,1-dimethylurea (DCMU) on two strains. Glucose and acetate both are quite effective in reversing the inhibitory action of both Stam f-34 and DCMU. The L-isomers of amino acids glutamine, cirtulline, arginine, methionine, valine and leucine individually support the mutant growth in nitrogen-free medium, while L-alanine fails to do so and L-glutamate is quite toxic to the growth of the parent strain. Stam f-34 or DCMU-inhibition of growth and heterocyst differentiation in both the parent and mutant strains is easily overcome by citrulline, methionine and valine. Neither herbicide is found to be mutagenic for inducing reversion to prototrophy in het^+ nif_{11}^- strain. These findings seem to suggest that Stam f-34 mode of action is like that of DCMU and that readily assimilable amino acids can serve as a good carbon and nitrogen source in *Nostoc muscorum*.

Vance, B.D., Drummond, W. (1969) Biological concentration of pesticides by algae. *J. Am. Water Works Assoc.* 61: 360. (NC)

Venkataraman, G.S., Rajyalakshmi. (1971) Tolerance of blue-green algae to pesticides. *Curr. Sci.* 40: 143–144. (NS)

Venkataraman, G.S., Rajyalakshmi, B. (1972) Relative tolerance of blue-green algae to pesticides. *Indian J. Agric. Sci.* 42: 119–121.

Summary: Twenty-seven strains of N_2-fixing blue-green algae belonging to four genera were tested for their *in vitro* tolerance to different concentrations of two fungicides and six herbicides. The algae showed a high but varied tolerance. In general, these algae could grow at high concentrations of the chemicals.

Watanabe, I., Subudhi, B.P.R., Aziz, T. (1981) Effect of neem cake on the population and nitrogen fixing activity of blue-green algae in flooded soil. *Curr. Sci.* 50(21): 937–939.

Summary: Neem cake stimulated the growth of blue-green algae in flooded soil possibly by depressing the activity of grazers, and enhanced photodependent N_2-fixation. Those effects were first observed in the greenhouse, and a similar trend was found in the field.

Wegener, K.E., Aldag, R., Meyer, B. (1985) Soil algae: Effects of herbicides on growth and C_2H_2 reduction (nitrogenase) activity. *Soil Biol. Biochem.* 17(5): 641–644.

Summary: The influence of the soil-applied herbicides chlortoluron, terbutryne, metabenzthiazuron, chloridazon, and dinosebacetate as well as the fungicide carbendazime on the growth and nitrogenase activity of soil algae was tested. The degree of algal cover on the soil surface was correlated with the measured C_2H_2-reduction (nitrogenase) activity. All the herbicides tested at recommended rates of application caused a total suppression of algal growth and C_2H_4 generation for several weeks. The fungicide had no detectable effect on algal populations or C_2H_2 reduction.

Wright, S.J.L. (1978) Interactions of pesticides with micro-algae. Pages 535–602 in *Pesticide microbiology*, Hill, I.R., Wright, S.J.L. (eds). Academic Press, London. (NS)

Notes: A review with 225 references.

Wright, S.J.L., Maule, A. (1982) Transformation of the herbicides propanil and chlorpropham by microalgae. *Pestic. Sci.* 13(3): 253–256.

Summary: Two species of green algae and four of blue-green algae hydrolyzed the acylanilide herbicide propanil to the aniline derivative, 3,4-dichloroaniline. Of the cultures tested, only the blue-green alga *Anacystis nidulans* was shown to be capable of converting the phenylcarbamate herbicides propham and chlorpropham to the corresponding anilines. The green alga *Ulothrix fimbriata* was apparently unable to hydrolyze propanil or chlorpropham.

Wright, S.J.L., Stainhorpe, A.F., Downs, J.D. (1977) Interactions of the herbicide propanil and a metabolite. 3,4 dichloroaniline, with blue-green algae. *Acta Phytopathol. Acad. Sci. Hung.* 12(1/2): 51–60.

Summary: At concentrations below those used for weed control, propanil significantly inhibited the photoautotrophic growth of several blue-green algae, including N_2-fixing species common in soil and ricefields. Sensitivity to propanil was affected by growth conditions. *Gloeocapsa alpicola* (unicellular) was the most propanil sensitive of the algae tested. Low concentrations (< 0.03 ppm) of propanil slightly stimulated some algae, intermediate concentrations (< 0.2 ppm) reduced growth in all species and caused cellular abnormalities in some, while concentrations above 5 ppm stopped photosynthesis and prevented algal growth. The metabolite 3,4-dichloroaniline (DCA), formed in algal cultures, was far less inhibitory than propanil to algal growth. Propanil addition to growing cultures of *A. cylindrica* caused a phase of lysis which was followed by recovery on continued incubation.

Wurtsbaugh, W.A., Apperson, C.S. (1978) Effects of mosquito control insecticides on nitrogen fixation and growth of blue-green algae in natural plankton associations. *Bull. Environm. Contam. Toxicol.* 19: 641–647. (NS)

Yamagishi, A., Hashizume, A. (1974) Ecology of green algae in paddy fields and their control with chemicals. *Zasso Kenkyu* 18: 39. (NC)

Yee, D., Weinberger, P., Johnson, D.A., Dechacin, C. (1985) In vitro effects of the S-triazine herbicide, prometryne, on the growth of terrestrial and aquatic microflora. *Arch. Environ. Contam. Toxicol.* 14(1): 25–32.

Summary: A green alga (*Chlamydomonas segnis*), a cyanobacterium (*Anabaena* sp.) and two N_2-fixing bacteria (*Klebsiella pneumoniae*, strain M5A1 and *Rhizobium japonicum*, strain 61A76) were separately exposed to concentrations of the S-triazine herbicide, prometryne, from 0.25–12.0 g/ml. Growth parameters observed included cell number (*C. segnis*), heterocyst frequency (*Anabaena* sp.) and generation time (*K. pneumoniae* and *R. japonicum*). A decrease in the population of *C. segnis* and heterocyst frequency of *Anabaena* sp. were noted after exposure to the herbicide. Full recovery was obtained in cleared cultures of *C. segnis* plated on pesticide-free nutrient agar. Similar recovery was not obtained in washed *Anabaena* sp. cells. *K. pneumoniae* was relatively insensitive to the herbicide; the generation time of *R. japonicum*, when exposed to 6.8 g/ml prometryne, was increased three-fold compared to untreated cultures (26.25 h vs. 9.5 h).

Zargar, M.Y., Dar, G.H. (1990) Effect of Benthiocarb and Butachlor on growth and nitrogen fixation by cyanobacteria. *Bull. Environ. Contam. Toxicol.* 45: 232–234. (NS)

Notes: *In vitro* experiments on a mixed culture of *Anabaena, Nostoc*, and *Oscillatoria* showed that 35 ppm Benthiocarb and 90 ppm Butachlor had no significant effect on algal dry weight produced in eight days.

Zeitseva, I.I. (1979) The influence of soil herbicides on the nitrogen fixing activity of blue green algae. *Mikrobiologie* 32: 60. (NC)

Zullei, N., Benecke, G. (1978) Application of new bioassay to screen the toxicity of polychlorinated biphenyls on blue-green algae. *Bull. Environm. Contam. Toxicol.* 20: 786–792.

Summary: A new bioassay was applied testing the toxicity of several PCB's and tetrachlorodibenzo-p-dioxin against blue-green algae. TCDD, mono-, di-, and trichlorobiphenyls inhibited the motility of *Phormidium* sp., while higher chlorinated biphenyls had no effect.

Zurek, L. (1982) The influence of the herbicides lenacil and pyrazon on soil algae. *Ekol. Pol.* 29(3): 327–342.

Summary: The influence of two herbicides, lenacil (cyclohexylo-5–6-trimethylenouracyl) and pyrazon (1-phenylo-4- = amino-5-chloro-6-ketopyrydasine), on soil algae was investigated under field and laboratory conditions. In the laboratory experiment, lenacil showed a higher and longer lasting toxicity than pyrazon. Its lethal doses in aqueous culture amounted to 0.0148 mg. dm^{-3} of medium for the blue-green alga *Anabaena variabilis*, and to 0.023 mg. dm^{-3} for the green alga *Chlorhormidium flaccidum*. The lethal doses of pyrazon amounted to 0.055 mg. dm^{-3} and 1.658 mg. dm^{-3}, respectively. Both herbicides impoverished the species composition and decreased the density of algal assemblages in plots.

Part 2. Pesticides Used in Experiments with Algae Occurring in Ricefields and Summary of Their Effects (*in vitro* and *in situ* Experiments)

Common names and commercial names are listed by alphabetic order.
Commercial names are referred to the common name.
The nature of the pesticide is indicated in the first parenthesis.

The chemical name (according to the International Union of Pure and Applied Chemistry, IUPAC) is indicated in the second parenthesis.
Information on recommended dose for application is indicated in kg/ha when available from the *Pesticide Manual* (Worthing and Walker, eds., 1983) and in lbs/acre when obtained from "Agriculturals chemicals" (Thomson, 1979); a question mark (?) indicates that recommended dose is neither available from these two reference books nor from the original paper.
Concentrations in ppm, kg/ha, and lbs/acre refer to active ingredient if not otherwise indicated. References listed without comments are dealing with the effects of the listed pesticide but do not include quantitative data that could be tabulated in terms of inhibition at a pesticide level expressed in ppm.

2,3-Dichloronaphthoquinone: see Dichlone

2,4-D, Weedone (herbicide) ([2,4-dichlorophenoxy] acetic acid): 2,4-D, its salts and esters are systemic herbicides at 0.28–2.3 kg/ha.

Arvik et al. (1971) *In vitro*, 400 ppm had no effect on *Chlorella vulgaris, Cylindrospermum licheniforme*, and *Chlorococcum* sp.
Bahal (1969) *In vitro*, simulative effect on heterocyst development in *Anabaena ambigua*.
Bednarz (1981) *In vitro*, Chlorococcal green algae were more sensitive than filamentous green and blue-green algae. Tolerant species decreased the toxicity of the herbicide to sensitive algae.
Das and Singh (1977b) *In vitro*, 100 ppm was not inhibitory for *Anabaenopsis raciborskii*.
Das and Singh (1978a)
Hawxby et al. (1977) *In vitro*, concentrations up to 10 µmol had no effect on *Lyngbia, Anabaena, Chlorococcum* and *Chlorella*.
Hamdi et al. (1970) *In vitro*, 0.045 ppm, 25 percent inhibition; 0.45 ppm, 45 percent inhibition; 4.5 ppm 30 percent inhibition on cultures of *Tolypothrix tenuis*.
Holst et al. (1982) *In vitro*, after 10 days, 0.1 and 1 ppm did not inhibit *Azolla* sp. growth on N_2, 10 ppm caused a total inhibition.
Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth was 50 ppm for *Aphanocapsa* 6714, 700 ppm for *Aphanocapsa* 6308, 100 ppm for *Anabaena variabilis*, and 250 ppm for *Nostoc* sp.
Inger (1970) *In vitro*, affect the growth of *Nostoc muscorum, Nostoc punctiforme* and *Cylindrospermum* at concentrations recommended for field

application, but was stimulatory at low concentrations -10^{-4}–10^{-5} M
M. Khalil et al. (1980) *In vitro*, 500 ppm was not algicidal for *Nostoc* sp., *Tolypothrix tenuis*, and *Mastigocladus laminosus*.
Mishra and Pandey (1989) *In vitro*, 100 ppm 2,4-D stimulated the growth and nitrogen fixation by *Nostoc linckia, Nostoc calcicola, Nostoc* sp., and *Anabaena doliolum*.
Padhy (1985)
Pandey and Tiwari (1986) *In vitro*, 100 ppm stimulated the growth of *Nostoc linckia*; 1500 ppm was lethal.
Pillay and Tchan (1972) *In vitro*, 1 and 5 ppm had no effect on the growth of *Chlorella* sp., *Scenedesmus* sp., *Chlorococcum* sp., *Chlamydomonas* sp., *Euglena* sp., *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp.
Schluter (1965) *In vitro*, little effect of 20 to 60 ppm 2,4D on cultures of three green algae, two BGA, and one diatom over a eight-week test period.
Shivaram and Shetty (1988) *In vitro*, 15 ppm had no negative effect at 30 days on the dry weight of *Anabaena variabilis, Calothrix* sp., and *Cylindrospermum musicola*. 5 ppm had no or little effect on *Hapalosiphon welwitschii, Nostoc* sp. and *Scytonema hofmani*.
P.K. Singh (1974) *In vitro*, at 16 days, 300 ppm was not inhibitory to *Cylindrospermum* sp.
R.P. Singh et al. (1986) *In situ*, 1.5 kg/ha had no significant effect on the composition of algal populations studied by direct counts.
Smith et al. (1977) *In situ*, control of BGA was not achieved with 2–3 ppm.
Srinivasan and Ponnuswami (1978) single dose of the formulation (Weedone 18 percent WP 2 kg/ha) decreased the production of BGA in inoculum multiplication plots by about 40 percent.
Subramanian and Shanmugasundaram (1986) *In vitro*, 100 ppm had no detrimental effect on BNF of three *Anabaena* strains, inhibited it by less than 50 percent in two strains and by more than 50 percent in one strain. 10 ppm had no effect on 5/6 strains and inhibited one by 50 percent. 1 ppm inhibited 1 strain by 40 percent.
Theivendirajah and Jeyaseelan (1981) *In vitro*, 64 ppm had no effect on *Nostoc carneum, Anabaena* sp., and *Anacystis nidulans*. 200 ppm was lethal.
Tiwari et al. (1981) *In vitro* 2,4-D increased the growth of *Nostoc linckia* at doses up to 100 g/ml.
Tiwari et al. (1982) *In vitro*, 100 ppm was stimulatory to *Anabaena cylindrica* growth.
Tiwari and Pandey (1981) *In vitro*, the growth of *Anacystis nidulans* was not affected by 500 ppm.
Venkataraman and Rajylakswami (1971) *In vitro*, 17 strains of BGA could grow at > 100 ppm, one at 50 ppm, and one at 5 ppm.

2,4,5-T (herbicide) ([2,4,5-trichlorophenoxy] acetic acid) Generally used in non crop areas. Used as post-emergence herbicide alone or with 2,4-D. Used at 1–12 lbs/acre (1.1–13.5 kg/ha) by aircraft or ground sprayers.

Padhy (1985)
Smith et al. (1977) *In situ*, control of BGA and green algae was not achieved with 2–3 ppm.

2,4,5-TP, Silvex (Herbicide) (2-(2,4,5-trichlorophenoxy) propionic acid) used at 1–4 lbs/acre (1.1–4.4 kg/ha)

Smith et al. (1977) *In situ*, control of BGA and green algae was not achieved with 2–3 ppm.

3-chloroaniline (herbicide):

Maule and Wright (1983) *In vitro*, 24 ppm had little effect on pigments of *Chlamydomonas reihardil* and *Anacystis nidulans*; more than 300 ppm was needed to significantly reduce O_2 evolution.

Agallol: see 2-methoxyethylmercury chloride

Alachlor, Lasso (herbicide, algicide) (2-chloro-2', 6'-diethyl-N-methoxymethyl acetanilide): Selective pre- or early post-emergence herbicide used at 1.7–4.5 kg/ha.

Hawxby et al. (1977) *In vitro*, concentrations up to 10 mol had no effect on *Chlorococcum, Lyngbia*, and *Anabaena* while 10 mol reduced *Chlorella* growth by 60 percent.
Holst et al. (1982) *In vitro*, after 10 days, 0.1 and 1 ppm partially inhibited *Azolla* sp. growth on N_2, 10 ppm caused a total inhibition.
Kumar and Singh (1981) *In vitro* at 10 days of growth, 1–20 ppm caused partial growth inhibition < 20 percent in *Anabaena doliolum*; 50 ppm was lethal. 1–5 ppm caused partial growth inhibition < 25 percent in *Nostoc* sp.; 10 ppm was lethal.
Mukerji and Laha (1979) *In situ*, 2.5 kg/ha was inefficient to control *Chara* and *Hydrilla.*
H.N. Singh et al. (1979) 200 ppm was lethal to *Nostoc muscorum.*

Aldicarb (insecticide) (2-methyl–2-(methylthio) propionaldehyde 0-methyl-carbamo yloxime): Soil-applied systemic pesticide used at 0.6–11.2 kg/ha.

Mallison and Cannon (1984) *In vitro*, at 31 days, 10 ppm inhibited the growth of *Plectonema borianum* by 30 percent.

Aldrex: see Aldrin

Aldrin, Aldrex (insecticide) ([1R,4S,4aS,5S,8R,8RaR]-1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphthalene): Insecticide highly effective against a range of soil-dwelling pests, its principal use is in agriculture at 0.5–5.0 kg/ha.

Batterton et al. (1971), Bongale (1985) *In vitro*, 10 ppm inhibit the growth of *Hapalosiphon* sp. by 6–23 percent, and *Nostoc microscopicum* by 50 percent.
Padhy (1985)
Schauberger and Wildman (1977) *In vitro*, 10 ppm had no effect on *Anabaena cylyndrica, Anacystic nidulans* and *Nostoc muscorum*; 50 percent inhibition was at about 50 ppm, 1,000 ppm was lethal.
Vance and Drummond (1969) *In vitro*, lethal dose was > 15 ppm for *Anabaena cylindrica*, < 5 ppm for *Microcystis aeruginosa*, > 20 ppm for *Senedesmus quadricauta*, and > 15 for *Oedogonium* sp.

Ametryne (herbicide) (2-ethylamino-4-isopropylamino-6-methylthio-1,3,5-triazine): used at 0.8–8 lbs/acre (1–9 kg/ha).

Mallison and Cannon (1984) *In vitro* at 14 days, 10 ppm completely inhibited the growth of *Plectonema borianum.*

Algaedyn (algicide) (?):

Padhy (1985)

Amitrole (herbicide) (1H-1,2,4-triazol-3-ylamine): Used in non crop areas. used at 1–20 lbs/acre (1.1–22.4 kg/ha).

DaSilva et al. (1974)
DaSilva et al. (1975) *In vitro*, 20 ppm stimulated BNF by nine strains of BGA; 20 ppm 3–5-D, a derivative, caused a temporary inhibition of BNF followed by stimulation in five of the nine strains.
Padhy (1985)

Atrazine (herbicide) (IUPAC 6-chloro-N-ethyl-N'-isopropyl-1,3,5-triazinediyl–2,4-diamine): used at 0.5–5 lbs/acre (0.6–5.6 kg/ha) (11–67 kg/ha for total control).

Allen et al. (1983)
Holst et al. (1982) *In vitro*, after 10 days, 0.1 ppm had no effect on *Azolla* sp. growth on N_2, 1 ppm caused a partial inhibition, 10 ppm caused a total

inhibition. Hotter et al. (1979) [The concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was 0.52 ppm for *Aphanocapsa* 6714, 0.04 ppm for *Aphanocapsa* 6308, 0.1 ppm for *Anabaena variabilis*, and 0.26 ppm for Nostoc sp.

Mallison and Cannon (1984) *In vitro* at 31 days, 10 ppm inhibited the growth of *Plectonema borianum* by 35 percent.

Maule and Wright (1984) *In vitro* experiment with seven green algae and six BGA, EC50 values ranged from 0.06 to 5.4 ppm.

Padhy (1985)

Pillay and Tchan (1972)

Rower and Fluckiger (1979)

Shabana (1987)

Stratton (1984) *In vitro*, EC50 values for *Chlorella pyrenoidosa, Scenedesmus quadricauda, Anabaena inaequalis, A. cylindrica*, and *A. variabilis* ranged from 0.1 to 0.5 ppm for photosynthesis and from 0.3 to 5.0 ppm for growth.

Stratton and Corke (1981) Photosynthesis inhibition was 0 at 0.01 ppm, 48 percent at 0.05 ppm, and 90 percent at 0.25 ppm with *A. inequalis*. It was 8 percent at 0.05 ppm, 33 percent at 0.25 ppm, and 65 percent at 0.5 ppm with *A. cylindrica*. It was 3 percent at 0.05 ppm, 60 percent at 0.10 ppm and 89 percent at 0.5 ppm with *A. variabilis*.

Barban (herbicide) (4-chlorobut-2-ynyl 3-chlorocarbanilate): Selective post emergence herbicide applied at 4–6 oz/acre (0.4–0.6 kg/ha).

Padhy (1985)

Basalin: see Fluchloralin

Bavistin: see Carbendazim

Benomyl (fungicide) (methyl-1-(butyl-carbamoyl)-2-benzimidazolyl carbamate): Systemic fungicide used at 0.15–0.5 kg ai/ha.

Cameron and Julian (1984)

Holst et al. (1982) *In vitro*, after 10 days, 10 ppm had no effect on *Azolla* sp. growth on N_2.

Ben(z)thiocarb, Saturn (herbicide) (S-(p-chlorobenzyl) diethylthiocarbamate): used at 3–6 kg ai/ha to the surface of the water 3–5 d before or 5–10 d after sowing or 3–7 d after transplanting.

Chen Pei Chung (1986) *In vitro*, 4 ppm had no effect on *Anabaena* CH_2 and CH_3, 6–10 ppm had a partial inhibitory effects.
El-Haddad (1984) *In vitro*, 4 ppm had no effect on growth and BNF of *Nostoc muscorum* and *Anabaena oryzae*, 10 ppm caused a partial inhibition.
El-Sawy et al. (1984) In pot, 4 kg/ha had no effect on inoculated *Nostoc muscorum* and *Anabaena oryzae*.
Kumar and Singh (1981) *In vitro*, at 10 days, 1–50 ppm caused partial growth inhibition in *Anabaena doliolum*; 50 percent inhibition was at 3 ppm. 1–4 ppm caused partial growth inhibition in *Nostoc linckia*; 50 percent inhibition was at < 2 ppm.
R.K. Singh et al. (1983) *In vitro*, 1 ppm already caused partial inhibition of *Nostoc* sp. 50 percent inhibition was at 2 ppm.
R.P. Singh et al. (1986) *In situ*, 1.5 kg/ha had no significant effect on the composition of algal populations studied by direct counts.
Zargar and Dar (1990) *In vitro* experiments on a mixed culture of *Anabaena*, *Nostoc*, and *Oscillatoria* showed that 35 ppm Benthiocarb had no significant effect on algal dry weight produced in 8 days.

Benzuride (algicide) (?):

Bisiach (1972a, b) *In vitro*, 8 ppm is inhibitory for *Spirogyra* and *Hydrodictyon*, and algicidal for *Oedogonium*.

BHC (insecticide) (Benzene hexachloride): used at 0.25–4.0 lbs/acre (0.30–4.4 kg/ha).

Das and Singh (1977a) *In vitro*, 60 ppm was inhibitory for *Anabaena raciborskii* and *A. aphanizomenoides*, 50 ppm was algistatic.
Das and Singh (1979) *In vitro* on *Microcystis flos aquae* 10 ppm did not affect the growth significantly, 10–80 ppm were algistatic and 100 ppm was algicidal.
Ishikawa and Matsuguchi (1966) In beakers experiments, at field level of application, had an inhibitory effect on diatoms but not on other components of the algal population.
Kaushik and Venkataraman (1983) *In vitro*, 1 and 10 ppm had no detrimental effect on ARA by *Hapalosiphon fontinalis, Hapalosiphon welwitschii, Westiellopsis prolifica, Westiellopsis* sp., and *Calothrix brauni*.
Padhy (1985).
Raghu and MacRae (1967) *In situ* 5 and 50 kg/ha promoted algal growth.
Sardeshpande and Goyal (1982) *In vitro*, 1 to 50 ppm partially inhibited N accumulation by *Anabaena iyengarii, Hapalosyphon intricatus, Calothrix*

membranacea, and *Calothrix bharadwaja* .. 50 percent inhibition was between 5 and 20 ppm.
Singh (1973) *In vitro*, at 18 days, 10 ppm inhibited *Cylindrospermum* by 18 percent but had no effect on *Aulosira fertilissima* at 50 ppm and on *Pectonema boryanum*, at 30 ppm.
Srinivasan (1981) *In situ*, 3.9 kg/ha significantly increased the production of BGA in inoculum production plots.
Subramanian (1982) *In vitro*, 10 ppm had no effect on four strains of *Anabaena*.

Blitane (fungicide, algicide) (37 percent metallic copper as Cu oxychloride + 22 percent Zineb):

Padhy (1985)

Blitox: see Copper oxychloride

Brassicol: see Quintozene

Brestan: see Fentin acetate

Bromacil (herbicide) (5-bromo-3-sec-butyl-6-methyluracil): Non-selective inhibitor of photosynthesis absorbed mainly through the roots and recommended for general weed control on uncropped land at 5–15 kg ai/ha. Used at 1.6–3.2 kg ai/ha for annual weed control.

Chen Pei Chung (1986) *In vitro*, no effect at 10 ppm on *Anabaena* CH_2 and CH_3.
Pillay and Tchan (1972).

Butachlor, Machete (herbicide) (N-butoxymethyl-2-chloro-2',6'-diethylacetanilide): Pre-emergence herbicide used at 1.0–4.5 kg ai/ha.

Chen Pei Chung (1986) *In vitro*, no effect at 10 ppm on *Anabaena* CH_2 and CH_3.
Kashyap and Pandey (1982) *In vitro* 0.5 to 10 ppm caused partial inhibition of *Anabaena dololium*, 2.5 ppm caused 50 percent reduction in growth, 20 ppm was algicidal.
Kerni et al. (1984)
Kumar and Singh (1981) *In vitro*, at 10 days of growth, 1–20 ppm caused partial growth inhibition < 20 percent in *Anabaena doliolum*; 50 ppm was lethal. 1–5 ppm caused partial growth inhibition in *Nostoc* sp.; 10 ppm was lethal.

Mishra and Pandey (1989) *In vitro*, 6–8 ppm was lethal on *Nostoc linckia*, *Nostoc calcicola*, *Nostoc* sp. and *Anabaena doliolum*.
Mukerji and Laha (1979) *In situ*, 2.5 kg/ha was algicidal to *Chara* and *Nitella* in seven days.
Padhy (1985)
Pandey and Kashyap (1986) *In vitro*, at 12 days or less, partial inhibition was observed at 0.5 ppm on the three tested strains; complete inhibition was observed at 2.5 ppm for *Anacystis nidulans*, 5 ppm for *Nostoc muscorum*, and 20 ppm for *Anabaena doliolum*.
Singh et al. (1987)
Singh and Vaishampayan (1978)
L.J. Singh et al. (1986) *In vitro*, 20 ppm had no effect on *Goeocapsa* while 10 ppm inhibited *Nostoc muscorum* by about 85 percent.
R.P. Singh et al. (1986) *In situ*, 1.5 kg/ha had no significant effect on the composition of algal populations studied by direct count.
Zargar and Dar (1990) *In vitro* experiments on a mixed culture of *Anabaena*, *Nostoc* and *Oscillatoria* showed that 90 ppm Butachlor had no significant effect on algal dry weight produced in eight days.

Camphechlor (insecticide) (a reaction mixture of chlorinated camphenes containing 67–69 percent chlorine):

Padhy (1985)

Captafol, Difolatan (fungicide) (N-(1,1,2,2-tetrachloroethylthio) cyclohex-4-ene-1,2-dicarboximide): Protectant non-systemic fungicide applied to foliage at c. 200 g ai/100 l.

Bisiach (1972) *In vitro*, 8 ppm is algicidal for *Spirogyra* and *Hydrodictyon*.
Gangawane and Saler (1979) *In vitro*, concentrations tolerated by various BGA were 300 ppm for *Westiellopsis* sp., 300 ppm for *Aulosira* sp., 100 ppm for *Calothrix* sp., 1,000 ppm for *Nostoc* sp., and 500 ppm for *Tolypothrix* sp.
Padhy (1985)

Captan, Hexacap: (fungicide) (N-(trichloromethylthio) cyclohex-4-ene-1,2 dicarboximide): used generally at 120 g ai/100 l.

Bharati and Angadi (1980)
Cameron and Julian (1984)
Gangawane and Saler (1979) *In vitro*, concentrations < 500 ppm had no effect on *Westiellopsis* sp., *Aulosira* sp., *Calothrix* sp., *Nostoc* sp. and *Tolypothrix* sp.

Gangawane et al. (1982), *In vitro*, 10 ppm was not inhibitory to *Nostoc* sp. and *Tolypothrix tenuis*.
Padhy (1985)

Carbaryl, NAC, Sevin (insecticide, molluscicide, grazer control) (1-naphthyl methyl carbamate): contact and stomach insecticide used at 0.25–2.0 kg ai/ha.

Adhikari (1989) Sevin had no significant effect on *Westiellopsis prolifica* growth measured *in vitro* 15 days after inoculation until 50 ppm, 50 percent inhibition was at 125 ppm, total inhibition was at 500 ppm.
Ahmad and Venkataraman (1973) no detrimental effect on *Aulosira fertilissima* when used at the recommended dose.
Ishizawa and Matsuguchi (1966) In beakers experiments had no significant effect at on algal populations when used at the recommended dose.
Megharaj et al. (1989a) *In vitro*, 20 ppm significantly increased the cell number of *S. bijugatus*. 5 ppm inhibited *Synechococcus elongatus*.
Megharaj et al. (1990) *In vitro*, 5 ppm had no effect on *Chlorella vulgaris*, 20 ppm caused 20 percent inhibition and 50 ppm 70 percent inhibition. 0.5 ppm had no effect on *Synechococcus elongatus*, 2 ppm caused 60 percent inhibition, and 5 ppm total inhibition. 10 ppm had no effect on *Nostoc linckia*, 20 ppm caused 20–50 percent inhibition.
Padhy (1985)
Sharma (1984)
Sinha et al. (1986) *In vitro*, 100 ppm is needed for use as molluscicide.
Srinivasan (1981) *In situ*, 2.4 kg/ha significantly increased the production of BGA in inoculum production plots.
Subramanian (1982) *In vitro*, 5 ppm had no effect on four strains of *Anabaena*, 50 ppm was lethal.

Carbendazim, Bavistin, MBC (fungicide) (methyl benzimidazol-2-ylcarbamate): banned in USA. Resistance has occurred. Used at ? kg/ha.

Gangawane (1980) *In vitro*, tolerant concentrations were 300 ppm for *Westiellopsis* sp., 100 ppm for *Aulosira* sp., 100 ppm for *Nostoc* sp., 50 ppm for *Tolypothrix* sp. while 1 ppm was algicidal for *Calothrix* sp.
Gangawane and Salers (1979) *In vitro*, concentrations lower than 1000 ppm had no effect on *Aulosira* sp. and *Tolypothrix* sp., concentrations lower than 500 ppm had no effect on *Calothrix* sp. and *Nostoc* sp., but 1 ppm was algicidal for *Westiellopsis* sp.
Gangawane et al. (1982) *In vitro*, 100 ppm was not inhibitory to *Nostoc* sp. and *Tolypothrix tenuis*.
Padhy (1985)

Wegener et al. (1985) In experiments with 23 g of non submerged soil carbendazime at 1, 2, and 3 times the recommended doses for field application had no major effect on algal growth and BNF.

Carbofuran, Furadan (insecticide, nematicide, molluscicide) (2,3-dihydro-2,2-dimethylbenzofuran-7-yl methylcarbamate): Systemic acaride, insecticide and nematicide, applied to foliage at 0.25–1.0 kg ai/ha and to seed furrow at 0.5–4.0 kg/ha.

Adhikari (1989) Carbofuran had no significant effect on *Westiellopsis prolifica* growth measured *in vitro* 15 d after inoculation until 3 ppm, 50 percent inhibition was at 7.5 ppm, total inhibition was at 30 ppm.
Ghost and Saha (1988) *In vitro*, 10 and 25 ppm significantly increased the chlorophyll content and dry weight of *Aulosira fertilissima*. Higher doses were found to be toxic. In soil cultures the tolerance was found to be much higher. Nitrogen fixation was encouraged up to 200 ppm during one and half month of incubation period.
Kar and Singh (1978) *In vitro*, 0.75 ppm enhanced growth and N_2-fixation by *Nostoc muscorum*, 1.5 –3 ppm was not or slightly inhibitory, 36 ppm was algicidal.
Kar and Singh (1979a, b, c) *In vitro*, depending on the level of nutrients in the medium, inhibition of the growth of *Nostoc mucorum* measured at 10 days was 23–55 percent with 7.5 ppm, 44–76 percent with 15 ppm, and 67–89 percent with 30 ppm.
Kaushik and Venkataraman (1983) *In vitro*, 10 ppm had no marked inhibitory effect on ARA by *Hapalosiphon fontinalis, Hapalosiphon welwitschii, Westiellopsis prolifica, Westiellopsis* sp. and *Calothrix brauni*.
Megharaj et al. (1988) In test tubes with soil, 0.5–2 kg/ha had no effect on total algal populations in flooded and non flooded soil at 10 and 20 days of incubation. 5 kg/ha had no effect in flooded soil but caused a transitory decrease in total algal population at 10 days in non flooded soil that disappeared at 20 days.
Megharaj et al. (1989a) *In vitro*, 20 ppm significantly increased the cell number of *Synechococcus bijugatus*. 5 ppm inhibited *Synechococcus elongatus*.
Padhy (1985)
Sardespande and Goyal (1982) *In vitro*, 1–20 ppm had no or little inhibitory effect on N accumulation by *Anabaena iyengarii, Hapalosiphon intricatus, Calothrix membranacea* and *Calothrix bharadwaja*. 50 ppm caused roughly 50 percent inhibition in the four strains.

Satapathy and Singh (1987) *In situ,* 0.15 kg ai/ha control insect pests of *Azolla* without detrimental effect on the fern.
Singh and Singh (1988) *In situ,* 90 g/ha favored *Azolla* growth.
Srinivasan (1981) *In situ,* 1.8 kg/ha significantly increased the production of BGA in inoculum production plots.
Tirol et al. (1981) *In situ,* 6 kg ai/ha promoted the growth of blue-green algae. Turbidity and an abundance of green algae distinguished the untreated floodwater from the carbofuran-treated one. The addition of up to 15 ppm ai (g/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.

Carboxin (fungicide) (5,6-dihydro-2-methyl-1,4-oxathi-ine-3-carboxanilide): Formulated alone or in combination with other fungicides. Used at 2–4 g/kg seed.

Cameron and Julian (1984) 2.3 ppm had no significant effect on *Nostoc* sp. growth. 23 ppm was lethal.
Padhy (1985)

Ceresan (fungicide) (N-(ethylmercury)-p-toluenesulphonanilide): Superseded compound banned in many countries.

Bharati and Angadi (1980)
Padhy (1985)
Sharma and Gaur (1980)
Venkataraman and Rajylakswami (1971) 15 strains of BGA could grow at 100 ppm, 3 at 10 ppm, and 4 were inhibited by 1 ppm.

Chloramben (herbicide) (3-amino-2,5-dichlorobenzoic acid): Selective pre-planting incorporated and pre-emergence herbicide applied at 2–4 lbs/acre (2.2–4.5 kg/ha).

Holst et al. (1982) *In vitro,* after 10 days, 10 ppm did not inhibit Azolla sp. growth on N_2

Chloridazon (herbicide) (5-amino-4-chloro-2-phenylpyridazin-3(2H)-one): Effective against broad-leaved weeds and used at 1.6–3.3 kg ai/ha.

Wegener et al. (1985) In experiments with 23 g of non submerged soil, chloridazon at recommended dose for field application inhibited algal growth and BNF for about two months.

Chlorodimeform (insecticide) (N'-(4-chloro-o-tolyl)-N,N-dimethyl-formamidine): used at ? ? kg/ha.

Mallison and Cannon (1984)

Chloropicrin (insecticide, nematicide) (trichloronitromethane): used at ? kg/ha).

Ishizawa and Matsuguchi (1966) Beaker experiments possibly showed some partial inhibition of algal populations for 1–3 weeks.
Padhy (1985)

Chlortoluron (herbicide) (3-(3-chloro-p-tolyl)-1,1-dimethylurea): Residual soil-acting herbicide and foliar spray, used at 1.5–3.0 kg ai/ha.

Amla and Kochhar (1982)
Wegener et al. (1985) In experiments with 23 g of non submerged soil chlortoluron, at recommended doses for field application (11 ppm), inhibited algal growth and BNF for about two months.

Chlorpropham (herbicide) (isopropyl 3-chlorocarbanilate): selective carbamate used at 2–8 lbs/acre (2.2–9 kg/ha)

Maule and Wright (1983) *In vitro*, 10 ppm reduced ARA of *Anabaena cylindrica* by 20 percent and 15 ppm by 40 percent. 20 ppm had no significant effect on the photosynthetic oxygen production of *Anacystis nidulans*.
Maule and Wright (1984) *In vitro* experiment with seven green algae and six BGA, EC50 ranged from 15 to 40 ppm for six BGA and 2 to 10 ppm for seven eukaryotic algae.

Chlorpyrifos (insecticide, molluscicide) (O,O-diethyl O-3,5,6-trichloro-2-pyridyl phosphorothioate): used at 0.1–5 lbs/acre (0.1–5.5 kg/ha).

Sinha et al. (1986) 50 ppm is needed to control snails.

Chlortalonil (algicide) (tetrachloroisophtalonitrile): used at 1–2 lbs/acre (1.1–2.2 kg/ha).

Battino-Viterbo et al. (1973) *In vitro*, 5 ppm is algicidal to *Anabaena* but 16 ppm had no effect on *Chlorella*.
Minervini Ferrante et al. (1974) *In vitro*, 50 percent inhibition of growth was at 10 ppm for *Oscillatoria* (44 percent) and > 16 ppm for *Cylindrospermum*, algicidal concentration was > 16 ppm for *Oscillatoria* and *Cylindrospermum*.

Copper chloride (algicide) ($CuCl_2$)

Kumar et al. (1985) *In vitro*, 0.2 ppm $CuCl_2$ had no significant effect on BNF by *Nostoc linkia*; 2 ppm caused about 20 percent inhibition in nitrogen fixation; 20 ppm caused about 50 percent inhibition in BNF and H_2 production.

Copper sulphate (fungicide, algicide): used at 1–25 lbs/acre (1.1–2.6 kg/ha).

Das (1976)
Dunigan and Hill (1978), *In situ*, 2 ppm Cu in the floodwater at the beginning of the crop when no floating algae were present permitted to control algal weeds.
Dunigan et al. (1979)
Gibson (1972) *In vitro*, 1 ppm was algicidal to *Anabaena flos-aquae* but 4 ppm only caused a partial inhibition of *Senedesmus quadricauta*.
Mukherji (1968)
Mukherji and Laha (1979) *In situ*, 12 kg/ha was algicidal to *Chara* and *Nitella*.
Mukherji and Sengupta (1964) *In situ*, 9–11 kg/ha could control *Chara* at the initial stage but there was no residual effect.
Pande et al. (1981) *In vitro*, LC_{50} for *Spirulina platensis* was 0.7 ppm Cu after 96 h. 0.5 ppm had no significant effect.

Copper dimethyl dithiocarbamate (?):

Padhy (1985)

Copper oxychloride, Blitox (fungicide) (dicopper chloride tryhidroxide): Foliage fungicide applied at 2–5 lbs/acre (2.2–5.5 kg/ha).

Gangawane et al. (1982) *In vitro*, 10 ppm was not inhibitory to *Nostoc* sp. and *Tolypothrix tenuis*.
Padhy (1985)
Vaishampayan and Prasad (1982)

Cotoron: see Fluometuron

Cyanazine (herbicide) (2-(4-chloro-6-ethylamino-1,3,5-triazin-2-ylamino)-2-methylpropionitrille): pre-and post-emergence use at 1–3 kg ai/ha, short persistence.

Holst et al. (1982) *In vitro*, after 10 days, 0.1 ppm had no effect on *Azolla* sp. growth on N_2, 1 and 10 ppm caused a partial inhibition.

Cypermethrin (insecticide) (alpha-cyano-3-phenoxyphenyl-3 (2,2-dichlorovinyl)-, 2-dimethyl cyclopropane carboxylate).

Megharaj et al. (1988) *In vitro*, no marked inhibition of *Nostoc linckia* by Cypermethrin was observed till 50 ppm.
Megharaj et al. (1989) *In vitro*, Cypermethrin had no effect at 5 ppm on the growth of *Scenedesmus bijugatus* measured after 20 d; 25 ppm caused a 40 percent inhibition. 10 ppm had no effect on the growth of *Synechococcus elongatus* and 25 ppm caused a 26 percent inhibition.

Dalapon (herbicide) (2,2-dichloropropionic acid): used at 0.75–20 lbs/ha (1–22 kg/ha) on many crops.

Padhy (1985)
Pillay and Tchan (1972) *In vitro*, 1 and 5 ppm had no effect on the growth of *Chlorella* sp., *Scenedesmus* sp. *Chlorococcum* sp., *Chlamydomonas* sp., *Euglena* sp., *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp.
Venkataraman and Rajylakswami (1971) *In vitro*, 23 strains of BGA could grow at 100 ppm, one at 10 ppm, and 3 at 1 ppm.

DCA (?) (2–3-dichloroaniline):

Padhy (1985)

DCMU: see Diuron

DDE: see DDT

DDT, DDE (insecticide) (major component 1,1,1-trichloro-2,2bis (4-chlorophenyl) ethane): used at 1–2 lbs/acre (1.1–2.2 kg/ha).

Batterton et al. (1972)
Chaudhari et al. (1989) *In vitro* 5 ppm inhibited *Scenedesmus* growth by 42 percent. *Chlorella* and *Spirulina* were tolerant at all doses of DDT.
Goulding and Ellis (1981) *In vitro*, whereas the growth of *Anabaena variabilis* was unaffected by 1 ppm DDT, the growth of *Chlorella fusca* was affected by 0.1 ppm.
Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was 4 ppm for *Aphanocapsa* 6714, 100 ppm for *Aphanocapsa* 6308, 100 ppm for *Anabaena variabilis*, and 50 ppm for *Nostoc* sp.
Kikuchi et al. (1984) *In vitro*, EC50 was > 100 ppm for *Chlorella vulgaris*, 4 ppm for *Nitzchia closterium* and 9 ppm for *Anabaena flos-aquae*.

Padhy (1985)
Subba-Rao and Alexander (1980) *In vitro,* 1 to 10 ppm had no marked effect on the chlorophyll content and biomass of *Chlorella vulgaris* measured as the average values and concentration in 8 and 13 days cultures. *In vitro,* 1 to 10 ppm had no marked effect on soil respiration measured for two to three days after pesticide application with classical respirometric techniques on 0.5 g of soil.
Vance and Drummond (1969) *In vitro,* lethal dose was > 15 ppm for *Anabaena cylindrica* and > 20 ppm for *Microcystis aeruginosa, Senedesmus quadricauta* and *Oedogonium* sp.

Deltan (?) (?):

Bongale (1985) *In vitro* 150 ppm was agicidal for *Hapalosiphon* sp. and *Nostoc microscopicum.*

Diazinon (insecticide, molluscicide, grazer control) (O,O-diethyl O-2-isopropyl-6-methylpyrimidin-4-yl phosphorothioate): used at 0.25–2 lbs/acre (0.3–2.2 kg/ha).

Ahmad and Venkataraman (1973) *In vitro,* no detrimental effect on *Aulosira fertilissima* at the recommended dose.
Mallison and Cannon (1984)
Padhy (1985)
P.K. Singh (1973) *In vitro,* at 18 days, 100 ppm had no effect on *Cylindrospermum, Aulosira fertilissima* and *Plectonema boryanum.*
Sinha et al. (1986) 50 ppm is needed for molluscicide use.
Srinivasan (1981) *In situ,* 3 kg/ha significantly increased the production of BGA in inoculum production plots.

Dicamba (herbicide) (3,6-dichloro-o-anistic acid): Foliar-or soil-applied herbicide, readily absorbed by leaves and roots and translocated throughout the plant. Dosage varies with specific use and ranges from 0.1 to 11 kg ai/ha.

Holst et al. (1982) *In vitro,* at 10 days, 10 ppm did not inhibit *Azolla* sp. growth on N_2.

Dichlone (fungicide) (2,3-dichloro-1,-4-naphthoquinone): Superseded compound. Used in swimming pools to control certain blue-green algae. Used at 0.25–0.5 lbs/acre (0.3–0.6 kg/ha).

Das (1976)
Fitzgerald and Skoog (1954)

Kashyap and Gupta (1981) *In vitro*, 0.1 to 0.5 ppm was partially inhibitory to *Nostoc muscorum, N. calcicola*, and *Anacystis nidulans*, 1 ppm was algicidal; *Anabaena cylindrica* tolerated concentrations 10 times higher.
Padhy (1985)

Dichlorophen, Panacide (fungicide, bactericide) (4,4'-dichloro-2,2'-methylene diphenol): applied at ? kg/ha.

Battino-Viterbo et al. (1973) *In vitro* is not algicidal at 14 ppm for *Anabaena* and *Chlorella.*
Gupta and Saxena (1974) *In vitro*, concentrations higher than 20 ppm were strongly inhibitory to *Scenedesmus, Chlorella, Myxosarcina* and *Aulosira.* 10 ppm was algicidal to *Nostoc* sp.
Minervini Ferrante et al. (1974) *In vitro*, 50 percent inhibition of growth was 2 ppm for *Oscillatoria* (44 percent) and between 8 and 16 ppm for *Cylindrospermum*, algicidal concentration was 4 ppm for *Oscillatoria* and > 16 ppm for *Cylindrospermum.*
Padhy (1985)

Dicofol, Kelthane (insecticide) (2,2,2-trichloro-1,1-bis (4-chlorophenyl) ethanol): Non-systemic acaricide with little insecticidal activity used at 0.56–4.5 kg ai/ha.

Mallison and Cannon (1984)

Dieldrin (insecticide) ((1R,4S,4aS,5R,6R,7S,8S,8aR)-1,2,3,4,10, 10-hexachloro-1,4,4a,5,6,7,8,8a-octahydro–6,7-expoxy-1,4:5,8-dimethanonaphthalene): Non-systemic and persistent insecticide of high contact and stomach activity to most insects. used at ? kg/ha (not used in US).

Batterton et al. (1971)
Padhy (1985)
Schauberger & Wildman (1977) *In vitro*, 10 ppm had no effect on *Anabaena cylyndrica, Anacystis nidulans and Nostoc muscorum*; 50 percent inhibition was at > 50 ppm; 1000 ppm was not lethal.
Vance and Drummond (1969) *In vitro*, lethal dose was >15 ppm for *Anabaena cylindrica*, < 5 ppm for *Microcystis aeruginosa*, and >20 ppm for *Senedesmus quadricauta* and *Oedogonium* sp.

Diflubenzuron, Dimilin (insecticide) (1-(4-chlorophenyl)-3-(2,6-difluorobenzoyl) urea): used at 0.02–0.14 lbs/acre (0.022–0.16 kg/ha).

Padhy (1985)
Wurtsbaugh and Apperson (1978)

Difolatan: see Captafol

Digust (?) (?):

DaSilva et al. (1974)

Dimethoate, Rogor (insecticide, acaricide) (O,O-dimethyl S-methylcarbamoylmethyl phosphorodithioate): Contact and systemic pesticide effective at 0.3–0.7 kg ai/ha.

Adhikari (1989) Rogor had no significant effect on *Westiellopsis prolifica* growth measured *in vitro* 15 d after inoculation until 15 ppm, 50 percent inhibition was at 30 ppm, total inhibition was at 300 ppm.
Bongale (1985) *In vitro* 10 ppm had no significant effect on *Hapalosiphon* sp. and *Nostoc microscopicum.*
Shivaram and Shetty (1988) *In vitro*, 6 ppm had no significant effect at 30 days on the dry weight of *Anabaena variabilis, Calothrix* sp., and *Cylindrospermum musicola*, and decreased it by about 20 percent in *Hapalosiphon welwitschii, Nostoc* sp. and *Scytonema hofmani.* 50 percent inhibition was observed at about 8 ppm for this three last strains. Sensitivity was higher when N_2-fixation was considered but was not significantly affected at 2 ppm.

Dimilin: see Diflubenzuron

Dinoseb, Dinoterb (herbicide) (2-sec-butyl-4,6-dinitrophenol): contact herbicide used at 2–4 kg ai/ha.

Hawxby et al. (1977) *In vitro*, concentrations up to 10 mol had no effect on *Chlorococcum* and *Anabaena* while 10 mol reduced *Lyngbia* growth by 50 percent and completely inhibited *Chlorella* growth.
Holst et al. (1982) *In vitro*, after 10 days, 0.1 ppm partially inhibited *Azolla* sp. growth on N_2, 1 ppm caused a total inhibition.
Khalil et al. (1980) 10 ppm was not algicidal for *Nostoc* sp., *Tolypothrix tenuis* and *Mastigocladus laminosus* but caused inhibition in growth by 60–80 percent.
Wegener et al. (1985) In experiments with 23 g of non submerged soil, dinoseb acetate at recommended doses for field application inhibited algal growth and BNF for about two months.

Dinoterb: see Dinoseb

Diphenamid, Enide (herbicide) (N,N-dimethyldiphenylacetsamide): Selective pre-emergence herbicide used to control grass and broad-leaved weeds at 4–6 kg ai/ha.

Mallison & Cannon (1984) as Enide

Diquat (herbicide, algicide) (9,10-dihydro-8a, 10a-diazoniaphenanthrene): applied at 1–2 kg/ha for aquatic weeds.

Das (1976)
DaSilva et al. (1975) *In vitro*, 20 ppm inhibited BNF by 9/9 BGA strains.
Holst et al. (1982) *In vitro*, at 10 days, 0.1 ppm partially inhibited *Azolla* sp. growth on N_2, 1 ppm caused a total inhibition.
Padhy (1985)

Dithane: see Mancozeb

Diuron, DCMU (herbicide) (3-(3,4-dichlorophenyl)-1,1-dimethylurea): Inhibits photosynthesis and is used for general weed control on non-crop areas at 10–30 kg ai/ha and 0.6–4.8 kg ai/ha on crops.

Addison and Bardsley (1968)
Amla and Kochhar (1982)
Allen et al. (1983)
Das (1976)
Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth was 0.01 ppm for *Aphanocapsa* 6714, 0.12 ppm for *Aphanocapsa* 6308, 0.01 ppm for *Anabaena variabilis*, and 0.05 ppm for *Nostoc* sp.
Mallison and Cannon (1984) *In vitro* at 14 d, was lethal to *Plectonema borianum.*
Maule and Wright (1984) *In vitro* experiment with seven green algae and six BGA, EC50 values were lower than 0.6 ppm in all cases.
Padhy (1985)
Pal and Chatterjee (1987) 10 ppm controlled seed formation in *Chara*, 50 ppm was toxic within 24 h of treatment.
Pillay and Tchan (1972) *In vitro*, 1 ppm partially inhibited the growth of *Chlorella* sp., *Scenedesmus* sp., *Chlorococcum* sp., *Chlamydomonas* sp., *Euglena* sp., *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp. 5 ppm was lethal to *Chlorella* sp. and *Euglena* sp. and partially inhibited *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp.
Pipe and Cullimore (1980) Small scale experiments (200 ml flasks) with

soil showed that 1 ppm decreased algal abundance by about 200 times in the first cm of a clay soil.
Vaishampayan (1984) Isolation of a mutant resistant to Diuron.
Venkataraman and Rajylakswami (1971) 14 strains of BGA could grow at > 100 ppm, five at 5–10 ppm.

Duter: see Fentin hydroxide

Ekalux: see Quinalphos

Endotaf: see Endosulfan

Endosulfan (insecticide, molluscicide) (C,C'-(1,4,5,6,7,7-hexachloro-8,9,10-trinorbon-5-en-2,3-ylene) (dimethyl sulphite) 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide): used at 0.2–4 lbs/acre (0.22–4.4 kg/ha).

Adhikari (1989) *In vitro*, endotaf had no significant effect on *Westiellopsis prolifica* growth measured *in vitro* 15 d after inoculation until 6 ppm, 50 percent inhibition was at 15 ppm, total inhibition was at 300 ppm.
Sardespande and Goyal (1982) *In vitro*, 1–50 ppm partially inhibited N accumulation by *Anabaena iyengarii, Hapalosyphon intricatus, Calothrix membranacea* and *Calothrix bharadwaja*. 50 percent inhibition was observed between 1 and 5 ppm.
Sinha et al. (1986) 10 ppm is needed for molluscicide use.

Endrin (insecticide) ((1R,4S,4aS,5S,7R,8R,8aR)-1,2,3,4,10,10-hexachloro-1,4,4a,5,6,7,8, 8a-octahydro-6,7-epoxy-1,4:5,8-dimethanonaphthalene): foliar insecticide which acts against a wide range of pests. Used at 0.2–0.5 kg ai/ha on upland rice.

Ahmad and Venkataraman (1973) *In vitro*, no detrimental effect on *Aulosira fertilissima* when used at the recommended dose.
Batterton et al. (1971)
Padhy (1985)
P.K. Singh (1973) *In vitro*, at 18 days, 100 ppm had no effect on *Cylindrospermum, Aulosira fertilissima* and *Plectonema boryanum*.
Vance and Drummond (1969)

Enide: see Diphenamid

Ethephon, Ethrel (plant growth regulator) (2-chloroethylphosphonic acid): Used to accelerate the pre-harvest ripening of fruit and vegetables.

Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was 200 ppm for *Aphanocapsa* 6714, 500 ppm for *Aphanocapsa* 6308, 200 ppm for *Anabaena variabilis*, and > 1000 ppm for *Nostoc* sp.

Ethirimol, Milstem (Fungicide) (IUPAC 5-butyl-2-ethylamino-6-methylpyrimidin-4-ol): Systemic fungicide effective against powdery mildews of cereals and other crops. Used at 0.5–1 lbs/acre (0.7–1.1 kg/ha).

Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was > 100 ppm for *Aphanocapsa* 6714, >100 ppm for *Aphanocapsa* 6308, 100 ppm for *Anabaena variabilis*, and 50 ppm for *Nostoc* sp.

Ethrel: see Ethephon

EPTC (herbicide) (S-ethyl dipropyl (thiocarbamate): Kills germinating weed seeds and inhibits bud development from underground portions of perennial weeds. Used at 3–6 kg ai/ha.

Padhy (1985)

Fenitrothion (Insecticide) (O,O-dimethyl O-(3-methyl-4-nitophenyl) phosphorothioate)

Kikuchi et al. (1984) *In vitro*, EC50 in ppm was > 100 for *Chlorella vulgaris*, 4 for *Nitzchia closterium* and 9 for *Anabaena flos-aquae.*

Fentin acetate, Brestan (fungicide, algicide) (IUPAC triphenyltin(IV) acetate): non-systemic, used at 160–260 g ai/ha.

Battino-Viterbo et al. (1973) *In vitro* 0.75 ppm is algicidal to *Anabaena* and 1 ppm to *Chlorella*
Bisiach (1972a, b) *In vitro*, 1 ppm is algicidal to *Spirogyra*, *Oedogonium* and *Hydrodictyon.*
Das (1976)
Minervini Ferrante et al. (1974) *In vitro*, 0.1 ppm partly inhibited the growth of *Oscillatoria* (44 percent) and *Cylindrospermum*, 0.5 ppm totally inhibited growth
Mukherji (1968)
Mukherji and Laha (1969) *In vitro*, 0.48 ppm was algicidal to *Chara* sp.
Mukherji and Ray (1966) *In situ*, 1.75 kg/ha controlled *Chara.*

Fentin hydroxide, Duter (fungicide) (triphenyltin hydroxide): Non-systemic fungicide for the control of early and late blights of potato at 250–350 g ai/ha.

Gangawane and Kulkarni 1979

Fenuron (herbicide) (1,1-dimethyl-3-phenylurea):

Das (1976)

Fenvalerate (Insecticide) (Cyano(3-phenoxyphenyl)-methyl)-methyl 4-chloro-alpha- (1-methylethyl) benzene acetate)

Megharaj et al. (1988) *In vitro*, no marked inhibition of *Nostoc linckia* was observed till 50 ppm.
Megharaj et al. (1989) *In vitro*, Fenvalerate had no effect at 10 ppm on the growth of *Scenedesmus bijugatus* measured after 20 d; 25 ppm caused a 10 percent inhibition. 25 ppm had no significant effect on the growth of *Synechococcus elongatus*.

Ferbam (fungicide) (iron tris [dimethyldithiocarbamate]): used for the protection of foliage against fungal pathogens at 175 g/100 l or 1–15 lbs/acre (1.1–16 kg/ha).

Das (1976)

Fernoxone (herbicide) (?): used at 20 kg formulation/ha.

Srinivasan and Ponnuswami (1978) single dose of the formulation reduced the production of BGA in inoculum multiplication plots by 25 percent.

Fluchloralin (herbicide) (N-(2-chloroethyl)-trifluoro-2,6-dinitro-N-propyl-p-toluidine): Preplanting or pre-emergence herbicide effective against grasses and broad-leaved weeds at 0.5–1 kg ai/ha depending on the crop and soil type.

Khalil et al. (1980) *In vitro*, 50 ppm was not algicidal for *Nostoc* sp., *Tolypothrix tenuis* and *Mastigocladus laminosus* but caused partial inhibitions of growth by about 70 percent.
Kumar and Singh (1981) *In vitro* at 10 days of growth, 20–30 ppm caused partial growth inhibition in *Anabaena doliolum* and *Nostoc linckia*; 40 ppm was lethal.
D.T. Singh et al. (1987)
L.J. Singh et al. (1986) *In vitro*, 20 ppm had no effect on *Gloeocapsa* but 10 ppm inhibited *Nostoc muscorum* by 75 percent.
Srinivason and Ponnuswami (1978) *In situ*, double dose of the formulation

(Basalin 48 percent 3 l/ha) had no effect on the production of BGA in inoculum multiplication plots.

Fluometuron, Cotoron (herbicide) (1,1-dimethyl-3-(3-trifluoro-m-tolyl) urea): mainly absorbed through the roots, weak activity through foliage. Used at 1.0–1.5 kg ai/ha.

Hawxby et al. (1977) *In vitro*, 1 mol inhibited *Lyngbia, Anabaena* and *Chlorella* growth by 50–75 percent but not *Chlorococcum.*
Mallison and Cannon (1984) *In vitro* at 31 days, 10 ppm inhibited the growth of *Plectonema borianum* by 10 percent.
Padhy (1985)
Venkataraman and Rajylakswami (1971) 21 strains of BGA could grow at > 100 ppm, two at 10 ppm and one at 1 ppm.

Fluorodifen (herbicide) (4-nitrophenyl alpha, alpha, alpha-trifluoro-2-nitro-p-tolyl ether): Pre- and post-emergence contact herbicide used at 3–4 kg ai/ha.

El-Sawy et al. (1984) In pot, 3 kg/ha had no effect on inoculated *Nostoc muscorum* and *Anabaena oryzae.*

Folpet (Fungicide, algicide) (?): used at 2–10 lbs/acre (2.2–11 kg/ha).

Bisiach (1972a, b) *In vitro*, 4 ppm is algicidal for *Spirogyra*, *Oedogonium* and *Hydrodictyum.*
Padhy (1985)

Fytolan (Fungicide) (copper oxychloride): used at 2–5 lbs/acre (2.2–5.5 kg/ha).

Gangawane (1980) *In vitro*, tolerant concentrations were 100 ppm for *Westiellopsis* sp., 100 ppm for *Aulosira* sp., 500 ppm for *Nostoc* sp., 500 ppm for *Tolypothrix* sp. and 100 ppm for *Calothrix* sp.
Padhy (1985)

Furadan: see Carbofuran

Gamma BHC: see BHC

Gamma HCH, HCH, Lindane: (insecticide, grazer control) (hexachloro-cyclo hexane [mixed isomers]): used at 0.25–4 lbs/acre (0.3–4.4 kg/ha).

Ahmad and Venkataraman (1973) *In vitro* no detrimental effect on *Aulosira fertilissima* when used at the recommended dose.
Das and Singh (1978a).

Das and Singh (1978b) *In vitro*, 60 ppm was inhibitory for *Anabaena raciborskii* and *A. aphanizomenoides*, 10 ppm was algistatic.
Kar and Singh (1979a, b) Depending on the level of nutrients in the medium, inhibition of the growth of *Nostoc muscorum* measured at 10 days was 8–57 percent with 2 ppm, 47–81 percent with 3 ppm, and 54–91 with 4 ppm.
Padhy (1985)
Sharma and Gaur (1980) Four strains of *Nostoc* sp. and one strain of *Aulosira fertilissima* tolerated 5–7 ppm in combination with other pesticides, three trains of *Aulosira fertilissima* tolerated 10 ppm.
Sharma and Gaur (1982)
Sharma (1984)
P.K. Singh (1973) *In vitro*, at 18 days, had no effect on *Cylindrospermum* at 80 ppm and on *Aulosira fertilissima* and *P. boryanum* at 200 ppm.

Glyphosate (herbicide) (N-[phosphonomethyl] glycine): Non selective post-emergence herbicide, used at 0.3–2.24 kg ai/ha.

Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was 100 ppm for *Aphanocapsa* 6714, 2 ppm for *Aphanocapsa* 6308, 2 ppm for *Anabaena variabilis*, and 2 ppm for *Nostoc* sp.
Maule and Wright (1984) *In vitro* experiment with 7 green algae and 6 BGA, EC50 values ranged from 70 to 600 ppm.

Goltix: see Metamitron

Hexacap: see Captan

HOE 2997 (algicide) (2-dichloracetamide-3-chloro-1,4-naphtoquinone): used at? kg/ha).

Battino-Viterbo et al. (1973) *In vitro*, is algicidal at 1 ppm for *Anabaena* and at more than 2 ppm for *Chlorella*.
Bisiach (1972a, 1972b) *In vitro* 2 ppm is algicidal for *Spirogyra*, and 1 ppm for *Oedogonium* and *Hydrodictyon*.
Das (1976)
Minervini Ferrante et al. (1974) *In vitro*, 50 percent inhibition of growth was at 2 ppm for *Oscillatoria* (44 percent) and 1 ppm for *Cylindrospermum*, algicidal concentration was 8 ppm for *Oscillatoria* and 2 ppm for *Cylindrospermum*.
Padhy (1985)

Iprodione, Rovral (fungicide) (3-(3,5-dichlorophenyl)-N-isopropyl-2,4-dioxo-imidazolidine-1-carboxamide): used at 0.5–1.0 kg ai/ha.

> Gangawane and Kulkarni (1979) *In vitro*, concentrations < 500 ppm had no effect on *Westiellopsis* sp., *Aulosira* sp., *Calothrix* sp., *Nostoc* sp., and *Tolypothrix* sp.

Isotox: see Gamma HCH

Kelthane: see Dicofol

K-Lox (algicide) (organic copper chelate): used at ? ? kg/ha.

> Dunigan and Hill (1978)
> Dunigan et al. (1979) *In situ*, 2 ppm Cu prevented algal growth if applied when no algae were blooming.

Lasso: see Alachlor

Lindane: see HCH

Linuron (herbicide) (3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea): used at 0.5–3 lbs/acre (0.6–3.4 kg/ha)

> DaSilva et al. (1974)
> DaSilva et al. (1975) *In vitro*, 10 ppm inhibited BNF by 4 of 9 strains of BGA and stimulated BNF by other strains after a temporary partial inhibition.
> Holst et al. (1982) *In vitro*, after 10 days, 0.1 and 1 ppm caused a partial inhibition of *Azolla* sp. growth on N_2, 10 ppm caused a total inhibition
> Padhy (1985)
> Venkataraman and Rajylakswami (1971) 15 strains of BGA could grow at > 100 ppm, 6 at 5–10 ppm, and two at 1 ppm.

Machete: see Butachlor

Magnacide-H (herbicide) (2-propenal): applied as aquatic herbicide up to 50 ppm.

> Fritz-Sheridan (1982) *In vitro*, 0.5 ppm had no effect on O_2 evolution by *Anabaena* sp., 2 ppm was algicidal.
> Padhy (1985)

Malathion (insecticide) (diethyl (dimethoxythiophosphorylthio) succinate): used at 0.5–3 lbs/acre (0.55–3.3 kg/ha).

DaSilva et al. (1974)
DaSilva et al. (1975) *In vitro*, 100 ppm caused partial inhibition of BNF follwed by stimulation in 6 of 9 strains of BGA.
Mallison and Cannon (1984) *In vitro* at 31 days, 10 ppm did not inhibit the growth of *Plectonema borianum.*
Padhy (1985)
Tandon et al. (1988) *In vitro*, *Anabaena* survived up to 500 μg/ml of malathion. *Aulosira* recovered to control levels only at 10 ppm.
Tiwari et al. (1979)

Mancozeb, Dithane (fungicide) (manganese ethylenebis (dithiocarbamate) (polymeric) complex of Zn and Maneb containing 20 percent Mn and 2.5 percent Zn): Protectant fungicide generally used at 1.4–1.9 kg ai/ha.

Bharati and Angadi (1980)
Bongale (1985) *In vitro*, 150 ppm was agicidal for *Hapalosiphon* sp. and *Nostoc microscopicum.*
Mukerji (1968)
Mukerji and Laha (1979) *In situ*, 6.25 kg/ha was algicidal in 21 days for *Chara* and *Nitella.*
Padhy (1985)
Shivaram and Shetty (1988) *In vitro*, 9 ppm had no negative effect at 30 days on the dry weight of *Anabaena variabilis, Calothrix* sp., *Cylindrospermum musicola, Hapalosiphon welwitschii, Nostoc* sp. and *Scytonema hofmani.* Some enhancement of N_2 fixed was observed at 3–9 ppm.
Subramanian (1982) *In vitro*, 7.5 ppm had no effect on 4 strains of *Anabaena*, 75 ppm was lethal.
Venkataraman and Rajylakswami (1971) concentrations of 50 ppm allowed the growth of 17/27 strains of BGA, 5 ppm the growth of 5/27 strains.

Maneb (fungicide) (manganese ethylenebis (dithiocarbamate) [polymeric]): Protectant fungicide used at 1.5–2.0 g/l to control many fungal diseases.

Padhy (1985)

MBC: see Carbendazim

MCPA (herbicide) (4-chloro-o-tolyloxyacetic acid): Hormone-type selective herbicide used at 0.28–2.25 kg ai/ha.

Ahmad and Venkataraman (1973) no detrimental effect on *Aulosira fertilissima* when used at the recommended dose, 100 ppm was not detrimental.

DaSilva et al. (1974)
DaSilva et al. (1975) *In vitro*, 25 ppm inhibited BNF by 8 of 9 strains of BGA.
Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was > 1,000 ppm for *Aphanocapsa* 6,714, > 1,000 ppm for *Aphanocapsa* 6308, 400 ppm for *Anabaena variabilis*, and 100 ppm for *Nostoc* sp.
Inger (1970) *In vitro*, affect the growth of *Nostoc muscorum, Nostoc punctiforme* and *Cylindrospermum* at concentrations recommended for field application, but was stimulatory at low concentrations—10^{-4}–10^{-5}M.
Maule and Wright (1984) *In vitro* experiment with 7 green algae and 6 BGA, EC50 values ranged from 90 to 300 ppm.
Padhy (1985)
Smith et al. (1977) *In situ*, control of BGA was not achieved with 2–3 ppm

MCPB (herbicide) (4-(4-chloro-o-tolyloxy) butyric acid): Selective post-emergence herbicide used at 1.7–3.4 kg ai/ha.

Ahmad and Venkataraman (1973) no detrimental effect on *Aulosira fertilissima* when used at the recommended dose, and at 100 ppm.
Padhy (1985)

MCPP: see Mecoprop

Mecoprop, MCPP (herbicide) ((±)-2-(4-chloro-o-tolyloxy) propionic acid): Systemic hormone-type post-emergence herbicide used at 1.5–2.7 kg/ha.

Hotter et al. (1979) *In vitro*, the concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was 250 ppm for *Aphanocapsa* 6714, 1000 ppm for *Aphanocapsa* 6308, 100 ppm for *Anabaena variabilis*, and 100 ppm for *Nostoc* sp.

Mephosfolan (insecticide) (diethyl 4-methyl-1,3-dithiolan-2-ylidenephosphor amidate): used at ? kg/ha.

Srinivasan (1981) *In situ*, 1.5 kg/ha significantly increased the production of BGA in inoculum production plots.

Metalaxyl (fungicide) (methyl N-(2-methoxyacetyl)-N-(2,6-xylyl)-DL-alaninate): used at ? kg/ha.

Mallison and Cannon (1984)

Metamitron (Herbicide) (4-amino-3-methyl-6-phenyl-1,2,4-triazine-5-(4H)-one): DCMU type herbicide used at 3.5–7 kg ai/ha

Gadkari (1987) *In vitro* 35 ppm ai was inhibitory to *Anabaena cylindrica* but 35 and 70 ppm ai was not inhibitory to *Nostoc muscorum.*

Metasystox R: see Oxydemeton-methyl

Metham, Vapam (fungicide) (methyldithiocarbamic acid): used at ? kg/ha.
Padhy (1985)

Methomyl (Insecticide)

Khalil and Mostafa (1986) *In vitro*, no significant effect on the growth of *Phormidium fragile* up to a concentration of 112 ppm.

2-methoxyethylmercury chloride, Agallol (fungicide): Used at ? kg/ha.
Bharati and Angadi (1980)

Methoprene (insecticide) (isopropyl (E-E)-(RS)-11-methoxy-3,7,11-trimethyldoodeca-2,4-dienoate): used at 15–20 g/ha.

Padhy (1985)
Wurtsbaugh and Apperson (1978)

Methoxychlor (insecticide) (1,1,1-trichloro-2,2-bis(4-methoxyphenyl) ethane): used at 0.25–0.50 lbs/acre (0.3–0.6 kg/ha).

Padhy (1985)
Wurtsbaugh and Apperson (1978)

Metolachlore (herbicide) (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide): Germination inhibitor active on grasses at 1.0–2.5 kg ai/ha.

Mallison and Cannon (1984)

Metribuzin (herbicide) (4-amino-6-tert-butyl-3-methylthio-1,2,4-triazin-5(4H)-one): used at 0.3–1 lbs/acre (0.4–1.1 kg/ha)

Arvik et al. (1973) *In vitro*, 1 ppm was algicidal to *Schizothrix calcicola, Anabaena* sp., *Chlorella vulgaris, Chlomydomonas* sp. and *Chlorococcum* sp., 0.05 ppm had a slight inhibitory effect
Gadkari (1987) *In vitro*, 7 ppm.ai was inhibitory to *Anabaena cylindrica* but concentrations up to 70 ppm had no effect on *Nostoc muscorum.*

Holst et al. (1982) *In vitro*, after 10 days, 10 ppm caused a partial inhibition of *Azolla* sp. growth on N_2.
Padhy (1985)

Mexacarbate (insecticide) (4-dimethylamino-3,5-xylyl methylcarbamate): Superseded compound. Used at ? kg/ha).

Padhy (1985)

Milstem: see Ethirimol

MnO_4K (algicide):

Bisiach (1972a, b) *In vitro*, 8 ppm is algicidal for *Spirogyra, Oedogonium* and *Hydrodictyon.*

Molinate, Ordram (herbicide) (S-ethyl azepane-1-carbothioate): Toxic to germinating broad-leaved and grassy weeds. Used at 2–4 kg ai/ha.

El-Haddad (1984) *In vitro*, 10 ppm had no effect on growth and BNF of *Nostoc muscorum* and *Anabaena oryzae.*
El-Sawy et al. (1984) In pot, 5 kg/ha had no effect on inoculated *Nostoc muscorum* and *Anabaena oryzae.*
Hamdi et al. (1970) *In vitro*, 0.25 ppm, 30 percent inhibition; 2.5 ppm, 30 percent inhibition; 25 ppm 80 percent inhibition on cultures of *Tolypothrix tenuis.*
Padhy (1985)
Smith et al. (1977) *In situ*, control of BGA and green algae was not achieved with 2–3 ppm.

Monocrotophos (insecticide) (dimethyl (E)-1-methyl-2-(methylcarbamoyl) vinyl phosphate): used at 0.5–1 lbs/acre (0.55–1.1 kg/ha). Fast-acting insecticide with both systemic and contact action, used at 250–500 g ai/ha against mites and sucking insects and 500–1000 g ai/ha against lepidopterous.

Bongale (1985) *In vitro*, 30 ppm have no inhibitory effect on *Hapalosiphon* sp. and N*ostoc microscopicum.*
Megharaj et al. (1988) *In vitro* 5 ppm inhibited growth of *Nostoc linckia* by 25 percent at and by 50 percent at 100 ppm
Megharaj et al. (1989) *In vitro*, monocrotophos had no effect at 10 ppm on the growth of *Scenedesmus bijugatus* measured after 20 d; 25 ppm caused a 40 percent inhibition. 25 ppm had no significant effect on the growth of *Synechococcus elongatus.*

Monuron (herbicide, algicide) (3-(4-chlorophenyl)-1,1-dimethylurea): Inhibitor of photosynthesis absorbed via the roots. Used at 10–30 kg ai/ha in noncrop areas.

Addison and Bardsley (1968)
Amla and Kochhar (1982)
Das (1976)
DaSilva et al. (1974)
DaSilva et al. (1975) *In vitro*, 10 ppm inhibited BNF by 9 of 9 strains of BGA.
Padhy (1985)
Pillay and Tchan (1972) *In vitro*, 1 ppm partially inhibited the growth of *Chlorella* sp., *Scenedesmus* sp., *Chlorococcum* sp., *Chlamydomonas* sp., *Euglena* sp., *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp. 5 ppm was lethal to *Chlorellla* sp. and *Euglena* sp. and partially inhibited *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp.
Vaishampayan (1984)
Vaishampayan (1985) 68 ppm fully inhibited a parent strain of *Nostoc muscorum* but a spontaneous mutant could support about 85 ppm.

Nabam (fungicide, algicide) (disodium ethylenebis [dithiocarbamate]): used at ? kg/ha).

Padhy (1985)

NAC: see Carbaryl

Naptalam (herbicide) (N-1-naphthylphthalamic acid): Inhibits seed germination. Used at 2.0–5.5 kg/ha.

Holst et al. (1982) *In vitro*, at 10 days, 10 ppm did not inhibit *Azolla* sp. growth on N_2.

Neburon (herbicide) (1-butyl-3-(3,4-dichlorophenyl)-1-methylurea): inhibits photosynthesis, is absorbed through plant roots and is used at 2–3 kg ai/ha.

Padhy (1985)
Pillay and Tchan (1972) *In vitro*, 1 ppm partially inhibited the growth of *Chlorella* sp., *Scenedesmus* sp., *Chlorococcum* sp., *Chlamydomonas* sp., *Euglena* sp., *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp. 5 ppm was lethal to *Chlorella* sp. and *Euglena* sp. and partially inhibited *Botrydiopsis* sp., *Nostoc* sp., *Anabaena* sp.

Nitrofen (herbicide) (2,4-dichlorophenyl 4-nitrophenyl ether): selective herbicide, toxic to a number of broad-leaved and grass weeds, and used at 2 kg ai/ha.

Das (1976)
Mukerji (1968)
Srinivason and Ponnuswami (1978) *In situ*, normal dose of the formulation (TOK E 25 emulsified concentrate at 9 l/ha) had no effect on the production of BGA in inoculum multiplication plots.

Ordram: see Molinate

Oxime-copper (fungicide) (bis(quinolin-8-olato) copper): Used at ? kg/ha).

Padhy (1985)

Oxydemeton-methyl, Metasystox R (insecticide) (S-2-ethylsulphinylethyl O,O-dimethyl phosphorothioate): used at 0.25–0.50 lbs/acre (0.3–0.6 kg/ha).

Mallison and Cannon (1984)

Panacide: see Dichlorophen

Paraquat (herbicide) (1,1'-dimethyl-4,4'-bipyridinium ion): destroys green plant tissue by contact action with some translocation. Used at 140–840 g ai/ha.

DaSilva et al. (1974)
DaSilva et al. (1975) *In vitro*, 20 ppm inhibited BNF by 9 of 9 strains of BGA.
Holst et al. (1982) *In vitro*, after 10 days, 0.1 ppm partially inhibited *Azolla* sp. growth on N_2, 1 ppm caused a total inhibition.
Padhy (1985)

Parathion (insecticide) (O,O-diethyl O-4-nitrophenyl phosphorothioate): Used at 0.1–1 lbs/acre (0.11–1.1 kg/ha).

Ahmad and Venkataraman (1973) *In vitro*, no detrimental effect on *Aulosira fertilissima* at 1–2 ppm.
Padhy (1985)

Parathion-methyl (insecticide) (O,O-dimethyl O-4-nitrophenyl phosphorothioate): Non-systemic contact and stomach insecticide. Used at 0.25–2 lbs/acre (0.3–2.2 kg/ha).

Ahmad and Venkataraman (1973)
Padhy (1985)

PCB (?) (Polychlorinated biphenyls): used at ? kg/ha.

Zullei and Benecke (1978)

PCP (insecticide, fungicide, herbicide, algicide) (Pentachlorophenol): used as wood preservative and to control vector snails in Egypt at ? kg/ha).

Ishizawa and Matsuguchi (1966) in beakers with 70 g dry soil, 120 ppm had a negative effect on total algal counts in floodwater at 3 days after application, there was a recovery after 1 week, with 600 ppm, recovery was observed after 3 weeks, with 1,200 ppm recovery was observed at 46 days. 120 ppm inhibited N_2-fixing BGA for one week but then increased their relative abundance, higher concentrations inhibited them for more than one month. This result was contradicted by a second experiment where PCP at field level was slightly inhibitory for BGA.
Mukerji (1972) *In situ*, algicidal against *Chara* and *Nitella* at 4–5 kg/ha but toxic to fish.
Padhy (1985)

Permethrin (insecticide) (3-phenoxybenzyl (1RS,3RS;1RS,3SR)-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate): Contact insecticide effective against a broad range of pests at 100–150 g ai/ha.

Padhy (1985)
Stratton (1980)
Stratton and Corke (1982)

PMA B: Used at ? kg/ha.

Padhy (1985)
Sharma and Gaur (1980) *In vitro*, tolerance was 0.05–0.3 ppm by 4 strains of *Nostoc* and 4 strains of *Aulosira fertilissima*.

Phorate, Thimet (insecticide) (O,O-diethyl S-ethylthiomethyl phosphorodithioate): Systemic and contact insecticide and acaricide used at 0.5–3 lbs/acre (0.33–5.5 kg/ha).

Bongale (1985) *In vitro*, 100 ppm had no significant effect on *Hapalosiphon* sp. and *Nostoc microscopicum*.

Gangawane (1979) *In vitro* was not deleterious to *Westiellopsis* sp., *Aulosira* sp., *Tolypothrix* sp. and *Calothrix* sp. at concentration of 300 ppm but 1 ppm inhibited *Nostoc* sp.
Kaushik and Venkataraman (1983)
Padhy (1985)
Saha et al. (1982) *In vitro*, 0.5 and 1 ppm stimulated BNF and increased chlorophyll content in *Nostoc* sp. (2).
Saha et al. (1984) *In vitro*, 5 ppm had no effect on N accumulation by *Nostoc muscorum* in N-free liquid culture, 25 ppm was lethal. 1 ppm had no effect on *Nostoc piscinale* and 10 ppm caused 50 percent inhibition. Experiments with 10 g soil inoculated with BGA showed an increase in total soil N up to at least 25 ppm.
Sardespande and Goyal (1982) *In vitro*, 1 ppm had no or little effect on N accumulation by *Anabaena iyengarii*, *Hapalosyphon intricatus*, *Calothrix membranacea* and *Calothrix bharadwaja*. 50 percent inhibition values were observed between 5 and 20 ppm. 50 ppm was inhibitory but not lethal for all the strains.
Satapathy and Singh (1987) *In situ*, 0.15 kg ai/ha controlled *Azolla* sp. pests with no detrimental effect on the fern.
Sinha et al. (1986) 50 ppm was needed for use as molluscicide.
Srinivasan (1981) *In situ*, 3.9 kg/ha significantly increased the production of BGA in inoculum production plots.

Phosvel (?) (?):

Sharma and Gaur (1980) *In vitro*, tolerance was 100–150 ppm by 4 strains of *Nostoc* sp. and 4 strains of *Aulosira fertilissima*.
Sharma and Gaur (1982)
Sharma (1984)

Picloram (herbicide) (4-amino-3,5,6-trichloropyridine-2-carboxylic acid): used at 0.3–3.3 kg ai/ha.

Arvik et al. (1971) *In situ* 0.28, 0.56, and 1.12 kg/ha of picloram caused no change in the composition of the algal flora over an 18-month period, regardless of dosage. *In vitro* it inhibited *Chlorella vulgaris*, *Cylindrospermum licheniforme* and *Chlorococcum* sp. at 50 ppm.
Padhy (1985)

Profluralin (herbicide) (N-(cyclopropylmethyl)-alpha,alpha, alpha-trifluoro-2,6-dinitro-N-propyl-p-toluidine): Soil-incorporated before planting at 0.75–1.5 kg ai/ha.

Hawxby et al. (1977) *In vitro*, concentrations up to 10 mol had no effect on *Lyngbia* and *Anabaena*, while 10 mol reduced *Chlorococcum* and *Chlorella* growth by 50 percent.
Mallison and Cannon (1984)

Prometone (herbicide) (2,4-bis(isopropylamino)-6-methoxy-1,3,5-triazine): non-selective herbicide used at 10–20 kg ai/ha on non crop areas.

Padhy (1985)

Prometryne (herbicide) (N,N'-di-isopropyl-6-methylthio-1,3,5-triazine-2, 4-diyldiamine): used either pre- or post-emergence at 1–1.5 kg ai/ha.

Addison and Bardsley (1968)
Hawxby et al. (1977) *In vitro*, 1 mol inhibited *Chlorella* and *Lyngbia* by 50 percent and 10 mol inhibited *Chlorella, Lyngbia*, *Chlorococcum* and *Anabaena* by 90–100 percent.

Propanil, Stam F-34 (herbicide) (3',4'-dichloropropionanilide): Contact herbicide recommended for post-emergence at 1–4 kg/ha.

Ahmad and Venkataraman (1973) [no detrimental effect on *Aulosira fertilissima* when used at the recommended dose.
El-Sawy et al. (1984) In pot, 12 kg/ha had some inhibitory effect on inoculated *Nostoc muscorum* and *Anabaena oryzae*.
Hamdi et al. (1970) *In vitro*, 0.18 ppm, 25 percent inhibition; 1.8 ppm, 45 percent inhibition; 18 ppm total inhibition on cultures of *Tolypothrix tenuis*.
Ibrahim (1972) *In vitro*, 1 ppm caused a partial inhibition on growth on *Tolypothrix tenuis* and *Calothrix brevissima*, complete inhibition was observed at 10 ppm.
Maule and Wright (1984) *In vitro*, EC50 values ranged from 0.09 ppm for *Chlorella pyrenoidosa* to 2.65 ppm for *Zygnema cylindricum*.
Maule and Wright (1984) *In vitro* experiment with 7 green algae and 6 BGA, EC50 values ranged from 0.1 to 2.65 ppm.
Padhy (1985)
Pandey (1985) *In vitro*, 0.5 to 20 ppm partially decreased growth and N_2 fixation by *Nostoc calcicola*, 30 ppm was lethal.
Pandey et al. (1984) *In vitro*, not mutagenic to *Nostoc calcicola*.

R.P. Singh et al. (1986) *In situ*, 1.5 kg/ha had no significant effect on the composition of algal populations studied by direct count.
Smith et al. (1977) *In situ*, control of BGA was not achieved with 3–6 ppm.
Srinivason and Ponnuswami (1978) *In situ*, single dose of the formulation (Stam F 30 applied at 10 l/ha) decreased the production of BGA in inoculum multiplication plots by about 15 percent.
Vaishampayan et al. (1978) *In vitro*, 1 ppm inhibited *Nostoc muscorum* by about 25 percent. 50 percent inhibition was observed at about 10 ppm.
Wright et al. (1977)

Propazine (herbicide) (6-chloro-N,N'-di-isopropyl-1,3,5-triazine-2,4-diyldiamine): Pre-emergence herbicide used at 0.5–3.0 kg ai/ha.

Padhy (1985)
Venkataraman and Rajylakswami (1971) 17 strains could grow at > 100 ppm, 5 at 5 or 10 ppm, and 3 at 1 ppm.

Propham (herbicide) (isopropyl carbanilate): used at 2.3–5.0 kg ai/ha.

Padhy (1985)

Propoxur (insecticide) (2- isopropoxyphenyl methylcarbamate): used at 0.2–1 lbs/acre (0.22–1.1 kg/ha).

Padhy (1985)
Wurtsbaugh and Apperson (1978)

Quinalphos (insecticide) (O,O-diethyl O-quinoxalin-2-yl phosphorothioate): contact and stomach insecticide and acaricide used at 190–500 g ai/ha.

Padhy (1985)
Srinivasan (1981) *In situ*, 1.8 kg/ha significantly increased the production of BGA in inoculum production plots.
Subramanian (1982) *In situ* 0.25 ppm had no effect on 4 strains of *Anabaena*. 5 ppm caused a transitory inhibition for about 10–15 days then growth resumed. 25 ppm was lethal
Megharaj et al. (1988) *In vitro*, inhibited *Nostoc linckia* growth by 10 percent at 5 ppm, 30 percent at 10 ppm and 100 percent at 20 ppm.
Megharaj et al. (1989) *In vitro*, Quinalphos at 5 ppm inhibited by 90 percent the growth of *Scenedesmus bijugatus* measured after 20 d; 10 ppm caused total inhibition. 5 ppm had no significant effect on the growth of *Synechococcus elongatus*. 10 ppm caused an inhibition by 16 percent, and 25 ppm caused a total inhibition.

Quintozene, Brassicol (fungicide) (pentachloronitrobenzene): used for seed treatment of as soil disinfectant at 5–200 lbs/acre (5.5–220 kg/ha).

Gangawane (1980) *In vitro*, 500 and 1,000 ppm caused partial inhibition in growth of *Westiellopsis* sp., *Aulosira* sp., *Nostoc* sp., *Tolypothrix* sp. and *Calothrix* sp.; lower concentrations had no effect.
Gangawane et al. (1982) *In vitro*, 1 ppm was not inhibitory to *Nostoc* sp. and *Tolypothrix tenuis*.
Padhy (1985)

Ricetrine (algicide) (organic copper chelate): Used at 15 lbs/acre in ricefields to control algae (16 kg/ha).

Dunigan and Hill (1978)
Dunigan et al. (1979) *In situ*, 2 ppm Cu prevented algal growth if used when no algae were blooming.

Roccal (algicide) (?):

Das 1976

Rogor: see Dimethoate

Rovral: see Iprodione

Ruberon (?) (mercuric ethyl phosphate):

Ishizawa and Matsuguchi (1966) In beakers experiments, had no effect significant effect at field dose on algal populations.

Saturn: see Simetryne

Sencor: see Metribuzin

Sevin: see Carbaryl

Silvex: see 2,4,5,-TP

Simazine (herbicide, algicide) (6-chloro-N,N'-diethyl-1,3,5-triazine-2,4-diyldiamine): used at 1–4 lbs/acre (1.1–4.5 kg/ha).

Das (1976)
Holst et al. (1982) *In vitro*, after 10 days, 10 ppm had no effect on *Azolla* sp. growth on N_2.

Goldsborough & Robinson (1986) *In situ* trials in swamp enclosures showed no reduction in total algal biovolume at 0.1 ppm simazine, with increasing inhibition (to 98 percent) at 1.0 and 5.0 ppm.
Kumar and Singh (1981) *In vitro* at 10 days of growth, 4–6 ppm caused partial growth inhibition < 20 percent with *Anabaena doliolum*; 8 ppm caused a 95 percent inhibition. 1–4 ppm caused partial growth inhibition with *Nostoc linckia*; 50 percent inhibition was at 2 ppm
Mallison and Cannon (1984)
Mehta and Hawxby (1979) *In vitro* 2 ppm caused a 50 percent reduction in growth in *Anacystis nidulans*
Padhy (1985)
Patnaik and Ramachandran (1976) *In situ*, 0.3–0.5 ppm simazine can efficiently control deleterious *Microcystis* blooms in fish ponds.
Pillay and Tchan (1972)
Tomaselli et al. (1987) *In situ* repeated use of simazine (4 kg/ha) affected more severely heterocystous BGA and strongly reduced species diversity.

Simetryne, Saturn (herbicide) (N,N'-diethyl-6-methylthio-1,3,5-triazine-2,4-diyldi amine): used at 4 kg/ha

Mishra and Pandey (1989) *In vitro*, 6–8 ppm Saturn was lethal on *Nostoc linckia, Nostoc calcicola, Nostoc* sp. and *Anabaena doliolum*.
Padhy (1985)
Srinivasan and Ponnuswami (1978) *In situ*, double dose of the formulation (Saturn 50 percent 16 l/ha) had no effect on the production of BGA in inoculum multiplication plots.

Stam F-34: see Propanil

TCA (herbicide) (trichloroacetic acid): applied at pre-emergence at 7–15 kg ai/ha.

Padhy (1985)

Temephos (insecticide) (O,O,O',O'-tetramethyl O,O'-thiodi-p-phenylene bis (phosphorothioate): used at 0.25–1 lbs/acre (0.3–1.1 kg/ha).

Padhy (1985)
Wurtsbaugh and Apperson (1978)

Terbuthylazine (herbicide) (N-tert-butyl-6-chloro-N'-ethyl-1,3,5-triazine-2, 4-diyldiamine): Controls a wide range of weeds, is absorbed mainly by plant roots, and is used at 1.2–1.8 kg ai/ha.

Hawxby et al. (1977) *In vitro*, 0.1 mol inhibited *Chlorella* and *Lyngbia* by about 50 percent; 10 mol had a marked inhibitory effect on *Lyngbia* and *Anabaena*, *Chlorococcum* and *Chlorella*.

Terbutryne (herbicide, algicide) (N-tert-butyl-N'-ethyl-6-methylthio-1,3,5-triazine-2,4-diyldiamine): Selective herbicide for pre-emergence used at 1–2 kg ai/ha.

Goldsborough & Robinson (1986) *In situ* trials in enclosures showed > 98 percent decrease of total algal biovolume at 0.01, 0.1 and 1.0 ppm terbutryn.
Muirhead et al. (1989)
Wegener et al. (1985) In experiments with 23 g of non submerged soil, terbutryne at recommended doses for field application inhibited algal growth and BNF for about two months.

Thimet: see Phorate

Thiophanate (fungicide) (diethyl 4,4'-(o-phenylene)bis(3-thioallophanate): used at ? kg/ha.

Gangawane and Kulkarni (1979)

Thiodicarb (insecticide) (?)

Sinha et al. (1986) *In situ*, 1 ppm reduced snail populations by 50 percent without detrimental effect on algae.

Thiram (Fungicide) (tetramethylthiuram disulphide): used at 1–6 lbs/acre (1.1–6.6 kg/ha).

Cameron and Julian (1984)
Gangawane et al. (1982) *In vitro*, 1 ppm inhibited *Nostoc* sp. but was not inhibitory to *Tolypothrix tenuis*.
Gangawane and Kulkarni (1979) *In vitro*, 1 ppm inhibited *Westiellopsis* sp., *Aulosira* sp. and *Calothrix* sp., concentrations lower than 1,000 ppm had no effect on *Nostoc* sp., concentrations lower than 300 ppm had no effect on *Tolypothrix* sp.
Hotter et al. (1979) The concentration causing a 50 percent reduction of photoautotrophic growth *in vitro* was 50 ppm for *Aphanocapsa* 6714, 100 ppm for *Aphanocapsa* 6308, 50 ppm for *Anabaena variabilis*, and 100 ppm for *Nostoc* sp.
Padhy (1985)

TOK: see Nitrophen

Tolkan: see Dinoseb

Topsin-M: see Thiophanate

Trifluralin (herbicide) (alpha,alpha,alpha-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine): Pre-emergence herbicide used at 0.5–1.0 kg ai/ha.

Hamdi et al. (1970) *In vitro*, 0.25 ppm, 25 percent inhibition; 2.5 ppm, 45 percent inhibition; 25 ppm 80 percent inhibition on cultures of *Tolypothrix tenuis*.
Holst et al. (1982) *In vitro*, after 10 days, 10 ppm did not inhibit *Azolla* sp. growth on N_2.
Ibrahim (1972) [1 ppm caused a partial inhibition on growth on *Tolypothrix tenuis* and *Calothrix brevissima*, complete inhibition was observed at 10 ppm for *Tolypothrix* and 100 ppm for *Calothrix*.
Padhy (1985)

Thimet: see Phorate

Vapam: see Metham

Weedone: see 2,4-D

Zineb (fungicide) (zinc ethylenebis [dithiocarbamate]): Used at 3–15 lbs/acre (3.3–16 kg/ha).

Das (1976)
Gangawane et al. (1982) *In vitro*, 1 ppm was not inhibitory to *Nostoc* sp. and 10 ppm was not inhibitory to *Tolypothrix tenuis*.
Padhy (1985)

Ziram (fungicide) (zinc dimethyldithiocarbamate): Used at 3–15 lbs/acre (3.3–15 kg/ha).

Padhy (1985)

Part 3. Tabulated Values of the Recommended Doses of Pesticides

Table D.1. Recommended Doses of Fungicides Tested *in vitro* or *in vivo* on Algae Recorded in Ricefields

	Recommended Dose (kg ai/ha)		
Fungicides	*Minimum*	*Maximum*	*Mean*
Benomyl	0.2	0.5	0.3
Captafol	0.3	2.0	1.1
Carbendazim	1.0	1.0	1.0
Carboxin	0.4	0.8	0.6
Copper oxychloride	2.2	5.5	3.9
Copper sulphate[a]	1.0	2.6	1.8
Dichlone	0.3	0.6	0.5
Ethirimol	0.7	1.1	0.9
Fentin acetate[a]	0.2	0.3	0.2
Fentin hydroxide	0.3	0.4	0.3
Ferbam	1.1	16.0	8.6
Folpet	2.2	11.0	6.6
Fytolan	2.2	5.5	3.9
Iprodione	0.5	1.0	0.8
Mancozeb[a]	1.4	1.9	1.7
Quintozene	5.0	200.0	103.0
Thiram	1.1	6.6	3.9
Zineb	3.3	16.0	9.7
Ziram	3.3	15.0	9.2
Minimum	0.2	0.3	0.2
Maximum	5.0	200.0	102.5
Median	1.0	2.0	1.7
Average	1.4	15.1	8.3
Standard deviation	1.3	45.1	23.0

a. Also used as algicide.

Table D.2. Recommended Doses of Herbicides Tested *in vitro* or *in vivo* on Algae Occuring in Ricefields

	Recommended Dose (kg ai/ha)		
Herbicides	*Minimum*	*Maximum*	*Mean*
2,4-D	0.3	2.3	1.3
2,4,5-T	1.1	13.5	7.3
2,4,5-TP	1.1	4.4	2.8
Alachlor	1.7	4.5	3.1
Ametryne	1.0	9.0	5.0
Amitrole	1.1	22.4	11.8
Atrazine	0.6	5.6	3.1
Barban	0.4	0.6	0.5
Ben(z)thiocarb	3.0	6.0	4.5
Bromacil	1.6	3.2	2.4
Butachlor	1.0	4.5	2.8
Chloramben	2.2	4.5	3.4
Chloridazon	1.6	3.3	2.5
Chlortoluron	1.5	3.0	2.3
Chlorpropham	2.2	9.0	5.6
Chlortalonil	1.1	2.2	1.7
Cyanazine	1.0	3.0	2.0
Dalapon	1.0	22.0	11.5
Dicamba	0.1	11.0	5.6
Dinoseb	2.0	4.0	3.0
Diphenamid	4.0	6.0	5.0
Diquat	1.0	2.0	1.5
Diuron	0.6	4.8	2.7
EPTC	3.0	6.0	4.5
Fluchloralin	0.5	1.0	0.8
Fluometuron	1.0	1.5	1.3
Fluorodifen	3.0	4.0	3.5
Glyphosate	0.3	2.2	1.3
Linuron	0.6	3.4	2.0
MCPA	0.3	2.3	1.3
MCPB	1.7	3.4	2.6
Mecoprop	1.5	2.7	2.1
Metolachlore	1.0	2.5	1.8
Metribuzin	0.4	1.1	0.8
Molinate	2.0	4.0	3.0
Monuron	10.0	20.0	15.0
Naptalam	2.0	5.5	3.8
Neburon	2.0	3.0	2.5

Table D.2. (Continued)

	Recommended Dose (kg ai/ha)		
Herbicides	*Minimum*	*Maximum*	*Mean*
Nitrofen	2.0	2.0	2.0
Paraquat	0.1	0.8	0.5
Picloram	0.3	3.3	1.8
Profluralin	0.8	1.5	1.1
Prometone	10.0	20.0	15.0
Prometryne	1.0	1.5	1.3
Propanil	1.0	4.0	2.5
Propazine	0.5	3.0	1.8
Propham	2.3	5.0	3.7
Ricetrine	1.0	16.0	8.5
Simazine[a]	1.1	4.5	2.8
Simetryne	1.1	4.5	2.8
TCA	7.0	15.0	11.0
Terbuthylazine	1.2	1.8	1.5
Terbutryne[a]	1.0	2.0	1.5
Trifluralin	0.5	1.0	0.8
Minimum	0.1	0.6	0.5
Maximum	10.0	22.4	15.0
Median	1.1	3.7	2.5
Average	1.7	5.5	3.6
Standard deviation	2.0	5.5	3.4

a. Also used as algicide.

Table D.3. Recommended Doses of Insecticides Tested *in vitro* or *in vivo* on Algae Occuring in Ricefields

	Recommended Dose (kg ai/ha)		
Insecticides	*Minimum*	*Maximum*	*Mean*
Aldicarb	0.6	11.2	5.9
Aldrin	0.5	5.0	2.8
Carbaryl	0.3	2.0	1.1
Carbofuran	0.5	4.0	2.3
DDT	1.1	2.2	1.7
Diazinon	0.3	2.2	1.3
Dicofol	0.6	4.5	2.5
Diflubenzuron	0.0	0.2	0.1
Dimethoate	0.3	0.7	0.5
Endosulfan	0.2	4.4	2.3
Endrin	0.2	0.5	0.4
Gamma HCH	0.3	4.4	2.4
Malathion	0.6	3.3	1.9
Methoxychlor	0.3	0.6	0.5
Monocrotophos	0.6	1.1	0.8
Oxydemeton-methyl	0.3	0.6	0.5
Parathion	0.1	1.1	0.6
Parathion-methyl	0.3	2.2	1.3
Permethrin	0.1	0.2	0.1
Phorate	0.3	5.5	2.9
Propoxur	0.2	1.1	0.7
Quinalphos	0.2	0.5	0.4
Temephos	0.3	1.1	0.7
Minimum	0.0	0.2	0.1
Maximum	1.1	11.2	5.9
Median	0.3	2.0	1.1
Average	0.4	2.5	1.4
Standard deviation	0.2	2.5	1.3

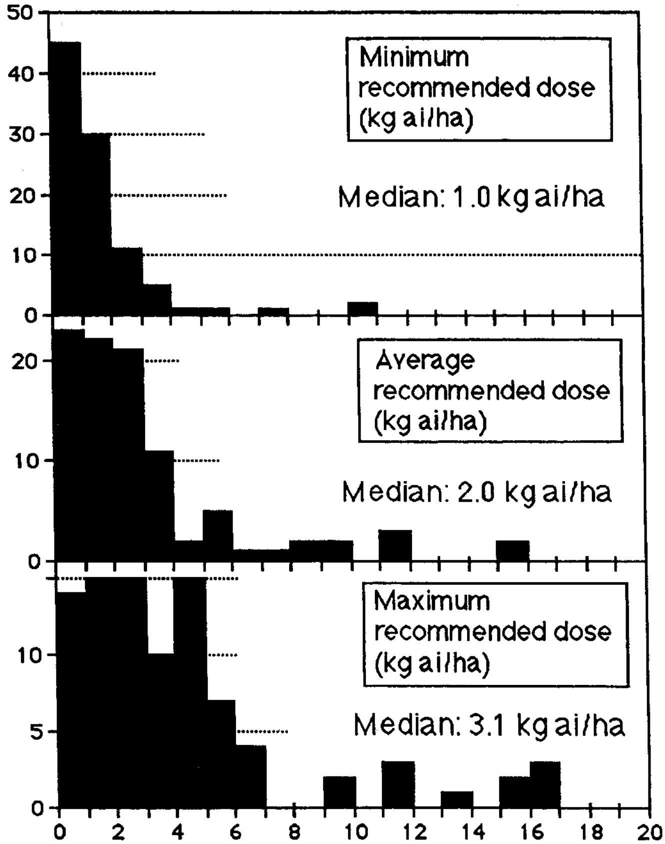

Figure D.3. Histograms of Minimum, Maximum, and Average Recommanded Doses of Pesticides Tested *in vitro* or *in vivo* on Algae Occuring in Ricefields