Effect of pesticides on nitrification

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INCREASED amounts of pesticides are applied to soil in addition to large amounts of these chemicals reaching soil from above ground pest control measures. Do these chemicals have side effects on sensitive microorganisms like nitrifiers? In the present review an attempt has been made to gather the information available on this aspect as whether the pesticides affect nitrification process, which is so important for nitrogen nutrition of plants and soil microflora. For systematic and exclusive presentation, the chemicals have been discussed under insecticides, herbicides, fungicides and soil fumigants. Each group has been further sub-grouped for discussion based on the chemistry of these chemicals.

INSECTICIDES

Although the effect of different insecticides has been extensively investigated, it still remains a subject of controversy. The effect of insecticides is discussed separately for different classes of chemicals.

(a) **Chlorinated hydrocarbons**. The nitrification inhibitory property of DDT was the first to be investigated starting with those of Wilson and Chaudhari (1946); Smith and Wenzel (1947); Harold (1952) and Brown (1954). These studies have brought out that nitrification is not affected by the insecticide even with the highest rates recommended for insect control. Smith and Wenzel (1947) also observed that BHC (containing 10-12 per cent gamma isomer) at 100 to 500 lb/acre reduced the population of nitrifying organisms, which remained low during the experiment upto 98 days but chlordane did not affect nitrification. Similar results have been reported by Harold (1952) and Gray (1954) with BHC and its gamma isomer. BHC (1000 ppm) and chlordane (1250 ppm) inhibited nitrification at high rates of application (Wilson, 1954). However, Harold (1952) and Fletcher and Bollen (1954) did not observe any effect of aldrin on nitrification in soil even at higher rates of application than recommended, which does not reconcile with the findings of Brown (1954) that chlorinated insecticides would inhibit nitrification at 0.05 per cent concentration.

Among the chlorinated insecticides tested at 12.5, 50 and 100 ppm, nitrate production was decreased by heptachlor, lindane and BHC but increased by toxaphene, TDE and DDT. Chlordane, methoxychlor, aldrin and dieldrin, however, had no effect (Eno and Everett, 1958). Nitrification was also not inhibited in a fertile loam on application of 10 to 100 lb a.i./acre aldrin or heptachlor and 30 to 300 lb a.i./acre chlordane (Shaw and Robinson, 1960).

Some interesting observations have been made by Sinha (1961) who found that in laboratory experiments, field levels of BHC stimulated nitrification but aldrin and chlordane depressed it with subsequent improvement after 50 days of application. Chandra (1967) from his studies concluded that some insecticides like dieldrin and heptachlor suppressed nitrification upto 8 weeks and the inhibitory effect decreased with increasing time and temperature of incubation in all soils, which may be due to adaptation of the responsible microorganisms to these chemicals (Chandra, 1964). It was observed that gamma BHC heptachlor and telodrin even at much higher levels than recommended did not adversely affect soil microbial population and appeared to stimulate nitrification and phosphorus mineralization (Jaiswal, 1967). Soils, dressed with ammonium sulphate treated with telodrin contained higher amounts of total ammonium nitrogen than untreated plots due to impaired nitrification (Srivastava, 1966). This and possible effects of other chlorinated insecticides benefited sugarcane crop and resulted in increased yields.

Bardiya and Gaur (1970) studied the effect of some chlorinated hydrocarbon insecticides on nitrification in soil. It was seen that inhibition of nitrification of ammonium sulphate in sandy loam (in laboratory) by 25 ppm or higher concentrations of insecticides was temporary (duration given in brackets) and followed the order : Lindane (3 weeks) > dieldrin (2 weeks) > aldrin (1 week). Decrease in nitrate levels was accompanied by nitrite accumulation. The results indicated that the insecticides tested do not harm nitrification at recommended field rates.

(b) **Organophosphates.** Systox and parathion at 65 and 250 ppm levels respectively appreciably inhibited nitrification in soils (Wilson, 1954). Singh and Gulati (1972) have reported that disyston and thimet insecticides at 100 ppm concentration had an adverse effect on ammonifiers and nitrifiers but the conversion from nitrite to nitrate nitrogen was not inhibited. It was found that the adverse effect of these insecticides on ammonification and nitrification, observed at initial stages, was nullified due to other degradation products of these chemicals in the soil.

The other classes of insecticides like carbamates have hardly been studied for their effects on nitrification.

HERBICIDES

It has been amply demonstrated that among the pesticides, herbicides are the toxic to nitrifiers and do not have any harmful effect when applied in recommended doses. It will be seen that the groups of herbicides extensively investigated are phenoxy acid derivatives and triazines although several others have also

(a) **Phenoxy-acid Derivatives.** Slepecky and Beck (1950) reported that 2,4,-D at 50 ppm concentration completely inhibited conversion of ammonia to nitrate but the action was reversible. On the other hand an increase in both ammonification and nitrification was observed with 2,4-D application by Voroev and Abueva (1958).

Application of 2,4-D enormously increased the nitrate content of soil, 2 to 5 months after application and also somewhat increased the mobile phosphorus content in laboratory studies (Dukhanin and Kolosova, 1962). Hale **et al.** (1957) studied the effect of Na-2,4- dichlorophenoxy ethyl sulphate, isopropyl N-(3-chlorophenyl) carbamate, alkanolamine salts of 4,6-dinitro-2-sec butyl phenol, 1,2-dichloro-propionic acid, 2-(2,4,5 trichlorophenoxy) propionic acid 3-(p-chlorophenyl) -1,1- dimethyl urea and Na- pentachlorophenate on the growth of soil nitrifying bacteria and concluded that at usual field rates little or no detrimental effect would occur on soil nitrification.

(b) **Substituted Ureides.** Urethanes have also been known for their inhibitory effect on soil nitrification and it seems that the process occurs (in presence of urethanes) only when organisms capable of breaking down these have developed (Quastel and Scholefield, 1951 and 1953). Urethanes also interfere with ammonia assimilation by nitrifying organisms at low concentration (Quastel, 1965). The nitrification of ammonia in soil was inhibited by 1.6 x 10^{-2} moles of Urethane for 8 days (Jaques **et al.** 1959). The substituted ureide, known as CMU is not only a powerful inhibitor of soil nitrification (Briggs and Segal, 1963) but is a powerful herbicide also. Isopropyl carbanilate and ethyl carbanilate both active herbicides have also been found inhibitory for soil nitrification.

(c) **Triazines.** Simazine and atrazine did not affect nitrification at normal field rates of application (Amataev **et al.,** 1963, Caseley and Luckwill, 1964). Tsvetkova (1966) on the other hand observed that simazine and atrazine, applied to podzolic soil (pH 5.3 and humus 2 per cent) increased nitrification to 10 folds and higher doses increased phosphorus and potash availability too.

In soil perfusion unit, simazine concentration of 6 to 9 ppm was found to slow down the rate of nitrification (Farmer **and Benoit, 1965). Setty et al.** (1970) reported that when applied to soil in conjunction with ammonium sulphate, atrazine at 10 ppm gave a higher nitrification rate after 2 weeks' incubation than the control soil or soil with higher rates of atrazine did, but after 5 weeks, the nitrification rate was lowest in soil receiving 10 ppm level of the chemical. Simazine upto 2.5 ppm did not interfere with the transformation of ammonia to nitrate in a sandy loam. Concentrations upto 10 ppm did not affect oxidation of ammonia to nitrite, but markedly inhibited transformation of nitrite to nitrate during first half of incubation (Nayyar **et al.,** 1970). It was further observed that simazine decreased the size of the bacterial population; but slightly increased the fungal population.

FUNGICIDES

Fungicides are very effective in retarding nitrification, even when applied at normal rates. The effect of dithiocarbamate fungicides was studied in detail. Nitrification of ammonium sulphate in soil was inhibited for about 28 days by ferbam at 3.5 x 10^{-4} mole/kg soil, for 25 days by manzate at 2.1 x 10^{-4} mole/kg soil and for 17 days by zineb at 2.1 x 10^{-4} mole/kg soil (Jaques et al., 1959). Munnecke and Ferguson (1960) did not observe any adverse effect at 112 kg/ha vapam on nitrification but the effect was noticed at 224 and 448 kg/ha. while the nitrification was completely inhibited at 896 kg/ha dose. Nabam at 100 ppm and mylone at 150 ppm completely suppressed nitrification for 30 days and 60 days. The nitrification rate again increased to approximately half of that shown by the control (Chandra and Bollen, 1961).

The effect of sodium pentachlorophenate, sodium trichlorophenate, tetrachlorophenates and pentachlorophenate fungicide mixtures on nitrification was studied by Mikkelsen (1965). There was some inhibition effect, which reflected in higher yields of rice in four out of 8 trials, where sodium pentachlorophenate was added. All the sulphur agents tested, specially sublimed sulphur and lime sulphur, inhibited nitrification when added to soil treated with ammonium sulphate or urea. supplying 400 ppm nitrogen (Hirabayashi **et al.,** 1967).

Out of the five fungicides tested by Caseley and Broadbent (1968) Lanstan (1-chloro-2-nitropropane), completely inhibited nitrification at 10 ppm, Chemagro 2653 (an isomeric mixture of 80 per cent 1,2,5-trichloro-4,6, dinitrobenzene) reduced the nitrification rate at 100 ppm concentration. Botran (2.6-dichloro-4-nitro-aniline) progressively inhibited nitrification, with complete inhibition at 100 ppm level. PCNB (1,2,4,5- pentachloronitrobenzene) and TCNB (1,2,4,5-tetrachloronitrobenzene) only slightly retarded nitrification even at a concentration of 100 ppm. Dubey and Rodriguez (1970) studying the effect of maneb and dyrene on nitrification found that when lateritic clay and fertile loam treated with 100 ppm ammoniacal nitrogen were mixed with 15-960 ppm of these fungicides and incubated at 24°C for 16 weeks, only ammonium oxidising bacteria were inhibited and the nitrite oxidising bacteria remained unaffected.

SOIL FUMIGANTS

Fumigants have a high nitrification depressing property, probably because they come in contact with a greater part of soil mass soon after application. Inhibition of nitrification process in soils by various fumigants such as telone, DD (a mixture of 1,3-dichloropropane and 1,2-dichloropropane), chloropicrin, methyl bromide, ethyldibromide and vapam has been reported from time to time by different works (Wolcott **et al.,** 1960; Winfree and Cox, 1958, Koike 1961; Mehta **et al.,** 1963; Tillet, 1964; Good and Carter, 1965; Abd-El Malek **et al.,** 1968).

In Hawaiian sugarcane soil, Koike (1961) found that some fumigants (DD, Telone, Dowfume W-85, EDB and vapam) depressed the nitrification rate for 4 to 8 weeks, whereas others (allyl alcohol, Nemagon or DBCP and PRDG-10) had less effect on nitrifying bacteria. Kirkwood (1963) observed that telone fumigant retarded nitrification and increased the availability of iron and manganese in celery, maize, and lettuce. Fumigation with methyl bromide brought down nitrification to a considerable extent over a period of 12 weeks. DD mixture and telone —EDB reduced nitrification temporarily and EDB did not retard at all (Tillet, 1964). In England, Gasser and Peachey (1964) tested Dazomet, DD, Methamsodium and methyl isothiocyanate and methyl bromide in glasshouse and field to control nematodes and observed that all these fumigants retarded nitrification and sometimes increased the amount of soil nitrogen mineralized. The maximum increase followed with methyl bromide treatment.

Suzuki and Watanable (1967) applied chloropicrin by point injection and row application into each point at 15 cm depth, followed by sealing with polythene film. They found that the nitrifying capacity of the soil was regained after 80 days but near the injection point 150 days were required for recovery. The nitrification of ammonium sulphate treated with DD fumigant was inhibited for 30 days, after which its toxic effect gradually disappeared (Zayed **et al.,** 1968).

From the information gathered in the present article the following broad conclusions can be drawn :

The pesticides, when used in their recommended levels of application hardly have any adverse effect on nitrification. Some of the classes of these chemicals may have a temporary retarding effect. But after the lag phase, the nitrifiers have their full activity depending upon the dose of the chemical and other edaphic characteristics.

These chemicals particularly herbicides have a stimulatory effect on nitrification as well as on plant growth when used in small amounts, which tend to show their conventional growth regulatory effect on microflora as well as higher plants. Such effects are also reflected in higher yields and better growth characteristics which cannot be accounted by their mere activity to control pests and diseases only and make us look towards their growth regulatory roles in addition to their usual plant protection functions. This role of these agricultural chemicals if established will give new dimensions to their use.

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