Effect of pesticides on availability of plant nutrients

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Introduction

A synergy between plant production and plant protection chemicals is essential for achieving higher and stabilized production of food, feed and fiber with the use of improved genetic resources under healthy soil environments. Therefore, larger amounts of agricultural chemicals are applied at present than before for fully exploiting the yield potentials of modern high yielding varieties. The present system of agriculture is also becoming more and more intensive. The land is always kept cropped to achieve an overall maximum production per unit area per unit time by adopting diversified cropping patterns under different farming systems. Such a system will have to be maintained by high levels of inputs. The soil under intensive agriculture will experience ecological changes influencing its micro-environment.

Under such an agricultural system it becomes all the more important to view the effects of agricultural chemicals used on long term basis. Results from such studies can be of immense help in planning to maintain the productivity of soils without degrading their native productive potentials. It thus becomes of paramount importance to study the effects of agricultural chemicals on important processes like nitrogen fixation, nitrification and on physical, chemical and biological properties of the soils including their influence on availability of plant nutrients. In earlier papers the effects of pesticides on nitrification and nitrogen fixation were reviewed and discussed (Sahrawat, 1974, 1975). The purpose of the present review is to gather the information on the aspect pertaining to the effects of pesticides on the availability of plant nutrients, so vital for crop growth. It is however, made clear at the outset that the availability of a nutrient is the net result of several biological, chemical and physical processes taking place in soil, which if affected by these biologically active chemicals may not only be sometimes reflected in the availability status of nutrients but also in the growth and yield performance of a crop.

Pesticides and increased growth response phenomenon

Many workers starting with the pioneering work of Waksman and Starkey (1923) have reported that the stimulation of plant growth with the soil application of pesticides is greater than that can be explained on the basis of the pesticidal action for control of pests. Because some workers have observed this phenomenon of increased growth (referred as increased growth response or IGR) even in the apparent absence of root parasitic organisms (Waksman and Starkey, 1923; Starkey and Waksman 1923a, b; Wilhelm. 1966; Altman and Tsue, 1965; Burrage **et al.**, 1967). The phenomenon of IGR is seemed to be caused by the increased release and availability of plant nutrients particularly nitrogen from the organisms killed by the pesticides and also from soil humus and minerals. This seems logical because the microbial cells contain many times higher quantities of nutrients like nitrogen and phosphorus as compared to plant materials. The phenomenon of IGR has been discussed in details by Martin (1972) along with possible explanations and theories and so will not be discussed in more details.

Some pesticides when applied to soil to control root parasites also inhibit the nitrification of fertilizer nitrogen resulting in better utilization of nitrogen by a crop, which can utilize ammonium form of N preferentially. Example of such effects of the pesticides can be found in the review made by Sahrawat (1974) and so will not be dealt in details but mention will be made of these where resulting in the changed uptake of nutrients and yields of crops. The effects of pesticidal chemicals on the availability of plant nutrients will be discussed under insecticides, herbicides, fungicides and fumigant heads.

Insecticides

Studies have been made with the persistent type of insecticides for their effects on the nutrient status of soils. The results reported by Boswell **et al.** (1955) indicate that the growth of vegetables like carrots, parsnips or turnips may be stimulated by common insecticides like DDT. The review of Martin (1972) summarizes the results, which show that some of the systemic insecticides, when applied to soil exert a positive effect and the crops stimulated are rice grains, cotton, potato and clover. Studies of Jaiswal

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(1967) with insecticides gamma BHC, heptachlor and telodrin showed that these insecticides had no adverse effect whatsoever on the microbial population but appeared to increase the mineralization of phosphorus. Soils dressed with ammonium sulfate treated with insecticide telodrin, contained higher amounts of ammonium nitrogen and benefited the sugarcane crop resulting in increased yields (Srivastava, 1966).

Varade and Ballal (1969) studied the effect of some common insecticides on the availability of plant nutrient in a black cotton soil and observed that the chlorinated insecticides like DDT, BHC endrin and chlordane had no effect on the availability of nitrogen and phosphorus at all concentrations varying from as low as 10 ppm to as high as 200 ppm. Work of Nair **et al.** (1973) pointed out that application rates of 0.45-2.25 kg a.i./ha of neither Sevidol, endrin nor gamma BHC had any adverse effect on the available nitrogen, phosphorus and potash status of the soil. Application of these insecticides on the other hand significantly increased the grain yield of rice, Sevidol being most effective and gamma BHC least effective in this respect.

In a laboratory study, Gaikawad **et al.** (1973) studied the effect of 16 soil biocides including five organophosphate insecticides two chlorinated insecticides and three others containing carbamates sulphurous esters and six weedicides on availability of N,P, K under flooded soil conditions. It was observed that application of these biocides had moderate stimulating effect on N.P.K availability during the first three months and available P during the entire period. Insecticide treatments resulted in slight increase in available K during the second month after which it decreased and followed the values similar to those in untreated soils. Vicario (1972) reported that malathion tended to decrease the P level of treated clay loam soil initially and then it slightly increased. K levels were affected slightly and the pH of soil remained unaffected by the insecticide treatment.

Thakre and Saxena (1972) on the other hand from greenhouse studies reported that DDT, endrin and lindane significantly reduced the dry matter of wheat whereas aldrin increased it. Growth of maize was increased by 20 ppm of aldrin and 20 and 30 ppm of endrin but decreased by 30 ppm of aldrin. 10 ppm DDT and lindane stimulated growth of maize but 20 and 30 ppm of lindane were toxic. DDT at 10 ppm enhanced N uptake by wheat and maize. Aldrin also stimulated nitrogen uptake at 10 and 20 ppm level in both wheat and maize but 30 ppm inhibited in maize only. In general lower levels of the insecticides increased P and K uptake by crops. It was interestingly observed that while in wheat all levels of lindane and 20 and 30 ppm of endrin reduced potassium uptake but 10 ppm aldrin increased the uptake. Narain (1975) observed that insecticides lindane and aldrin when used at 5 kg/ha rates with ammonium sulphate, urea and ammonium nitrate did not significantly affect the N, P and K, content in rice in pot culture experiments.

Herbicides

It has been observed from the review of literature (Sahrawat 1974) that the amount of herbicides required to have a depressing effect on processes like nitrification are many times higher than those recommended and same is true for other microbial processes.

Dukhanin and Kolosova (1962) found that in laboratory studies 2-4-D showed a tendency to increase the mobile P content and nitrate nitrogen in soils. Similarly Tsvetkova (1966) reported that in a podzolic soil higher rates of simazine and atrazine herbicides increased phosphorus and potash availability.

It was observed that 2,4-D tended to increase the levels of P, K, Ca and total N above the level of the control in a clay loam soil. MCPA — potassium tended to decrease the P level of treated soil for 3 weeks but then increased it and caused slight fluctuations in K levels and reduced total N particularly in the 5th week. MCPA increased calcium content during the first week. No treatment affected the soil pH (Vicario, 1972).

Very interesting results have been reported by Steenbjerg **et al.** (1972) about the effect of nitrogen and simazine on the utilization of various plant nutrients. They found that in pot experiments with oats, the supply of N and simazine were inversely related in such a way that when there was only a limited quantity of N present, the amount of N absorbed was almost independent of the simazine, but the concentration of the nutrient rose sharply in the plant with the application of simazine. It was concluded that the influence of simazine on the absorption of a plant nutrient and on its concentration in the plant seemed to be strongly dependent on the quantity of nutrient present. Gaikawad **et al.** (1973) reported that the weedicides MCPA, nitrofen, propanil, Molinate, potassium azide under flooded soil conditions had a stimulatory effect on the availability of N, P and K during the first three months and available P during the entire period. Application of weedicides resulted in marked increase in K availability during the second and fourth months.

Chesalin and Timofeeva (1975) using ^{15}N tagged nitrogen found that application of atrazine increased uptake of applied nitro-

gen by maize plants ,tolerant of atrazine) and had no significant effect on their N metabolism but in sunflower (susceptible) plants it decreased uptake of ^{15}N and inhibited protein synthesis.

Fungicides

Fungicides are applied either as seed dressing or through soil to control the seed or soil borne fungi and their rates are generally lower than those of insecticides and herbicides. It has been generally observed that these chemicals are degraded in soils and act as source of nutrients to microorganisms and in turn may release the constituent elements of these chemicals especially micronutrients like Fe, Mn, Zn, etc. But there are very few reports about the effects of fungicides on availability of plant nutrients. In very few cases micronutrient toxicity has been reported by fungicide treatments.

Nishihara (1962) reported that fungicides like Vapam, PMF, Maneb increased the growth of rice plants especially number of tillers, grain and straw yield and nitrogen uptake. This was ascribed due to inhibition of nitrification and reduced losses of N due to leaching and denitrification in presence of these fungicidal chemicals.

Similarly Mikkelsen (1965) used sodium pentachlorophenolate, sodium trichlorophenolate, tetrachlorophenolate and the mixtures of these fungicides to study their effect on the yield performance of rice due to their possible nitrification inhibitory influences. There was some inhibition effect, which was reflected in higher yields of rice in four out of 8 trials, where sodium pentachlorophenolate was added. This study indicates the better utilization of nitrogen due to its more availability in presence of fungicides.

Fumigants

Due to high vapor pressures of the fumigant chemicals even their small amounts come into contact with large volumes of soils and this may result in changed microbial activity resulting sometimes increased amounts of certain nutrients especially micro-elements constituting the fumigant. In one of the studies Klemmer (1957) reported that application of DD increased the availability of nitrogen at lower rates due to decomposition of soil organic matter by fumigant resistant bacteria. Kirkwook (1963) found that telone fumigant increased the availability of iron and manganese in maize, celery and lettuce. Jenkinson **et al.** (1972) observed that fumigation with methyl bromide or formaldehyde increased the growth of wheat and rye grass not given fertilizer nitrogen probably due to mineralization and availability of soil nitrogen. However, fumigation with methyl bromide left ionic bromide in the soil and this depressed the growth of wheat receiving fertilizer nitrogen. Formaldehyde also left residues. Perhaps the residual effect from these fumigants influenced soil metabolism and sometimes depressed the growth of plants given fertilizer nitrogen.

Recently Singhal **et al.** (1975) studied the effect of DD mixture on the availability of plant nutrients and observed that fumigants while in smaller doses significantly stimulated the availability of nitrogen and phosphorus, higher doses tended to be toxic. Lower rates had a non significant suppressive effect on K availability but organic matter was significantly reduced with increasing rates of DD mixture. There are some studies which indicate that the fumigation of soils sometimes results in the increases in Ca, Mg, K, P, S, Zn, Mn and other elements in the saturation extracts. Chloride is also sometimes markedly increased following fumigation with D-D mixture (Martin 1972) and this may sometime be of consequence to plant nutrition. Martin (1972) has reviewed and described the results of earlier studies in which it was noted that D-D, CS_2 and chloropicrin fumigation increased calcium and slightly increased the K and Mg in the saturation extracts of both greenhouse and field soils. These increases were apparent even after 100 days and higher concentrations of Ca were reflected in the increased absorption of calcium by citrus plants. Extractable P has also been reported to increase following fumigation of soils.

There are reports which show that fumigation of some soils increases soluble and exchangeable Mn and also Cu and Zn as indicated by both plant and soil analyses (Aldrich and Martin, 1952). Some workers have observed that fumigation of soils with methyl bromide increased the Mn content of spruce seedlings and others reported that fumigation of Hawaiian soils with D-D sometimes increased both extractable iron and alluminum (Martin, 1972).

Conclusions

The following valid conclusions can be drawn from this review of litrature : (1) Most of the pesticidal chemicals applied at recommended rates have little if any effect on the availability of plant nutrients, (2) Some insecticides and herbicides sometimes show stimulating effect on the availability of nutrients like nitrogen, phosphorus and potassium. (3) Fumigation has been found to increase the availability of major as well as minor elements due to mineralization of soil organic matter and decomposition of these chemicals and mineralization of nutrients from the soil biomass. These changes in nutrient status of soils have been reported to have beneficial effects on growth of plants. (4) There are very few

reports showing the adverse effects on the availability of nutrients due to pesticide application at recommended rates. (5) But higher rates of fungicides and fumigants, sometimes temporarily block absorption of some major as well as minor elements in plants.

REFERENCES

1. Aldrich. D.G. and Martin, J.P. 1952. Effect of fumigation on some chemical properties of soils. *Soil Sci. 73*: 149-59.
2. Altman, J. and Tsue, C.M. (1955). Changes in plant growth with chemicals used as soil fumigants. *Plant Disease Reptr. 49*: 600-602.
3. Boswell, V.R.. Clare, W.G., Peeper. B.B., Taylor, C.B. and Gilmore, P.M. (1955) *USDA Tech. Bull 1121*: 1-59.
4. Burrage, R.H., Menzies, J.A. and Zirk, E. (1967). Soil treatments with broadcast or band applications of organophosphorus or carbamate insecticides for prevention of wireworm damage to potatoes. *J. Econ. Entomol. 60*: 1489-492.
5. Chesalin, G.A. and Timofeeva, A.A. (1975). A study using ^{15}N on the effect of some herbicides on nutrient metabolism in plants. *Field Crop Abstr. 28* (10): 6965.
6. Dukhanin, A.A. and Kolosova, A.A. (1962). Effects of 2,4-D on nitrate phosphate regime of study in chernozemic soils. *Trnty. Vsesoyng Mauch Issled. Inst. Udobr. Agropochvoved 39*: 226-32.
7. Gaikawad, S.T., Samantaray, R.N. and Patnaik, S. (1973). Effect of soil application of biocides on NPK availability and C, N transformations in flooded rice soils. *J. Indian Soc. Soil Sci. 21*: 263-69.
8. Jaiswal. S.P. (1967). Effects of some pesticides on soil microflora and their activity. *J. Res. PAU. 4*: 223-26.
9. Jenkinson. D.S., Nowakowski, T. Z. and Mitchell, J.D.D. (1972). Growth and uptake of nitrogen by wheat and ryegrass in fumigated and irradiated soil. *Pl Soil 36*: 149-58.
10. Kirkwood, J. I. (1963). Effects of fumigant chemicals on microbial activity and nitrogen rtansformation and on crop response in organic soils. *Diss. Abstr. 23*: 3581-582.
11. Klemmer, H.W. (1957). Response of bacterial, fungal and nematode populations of Hawaiian soils to fumigation and liming. *Bact. Proc. 57*: 12 (All).
12. Martin, J.P. (1972). Side effects of organic chemicals pp. 733-792. *In "Organic Chemicals In the Soil Environment,"* C.A.I. Goring and J. M. Hamaker (ed) Marcel Dekker Inc. N.Y.
13. Mikkelsen, D.S. (1965). Use of chlorinated phenols as nitrification inhibitors in rice fertilization. *Rice J. 68* (7): 74-5.
14. Narain, P. (1975). Effect of nitrogen sources along with N-Serve, lindane and aldrin on uptake of nitrogen, phosphorus and potash in rice. *II Riso 24* (3): 245-50.
15. Nair, K. S., Ramakrishnan, C. and Sithanantham, S. (1973). Effect of soil application of insecticides on the nutrient status, bacterial populations and yield in rice soils. *Madras agric. J 60*: 441-43.
16. Nishihara, T. (1962). The search for chemical agents that efficiently inhibit nitrification in soil and the studies on its utilization to agricultural practice. *Bull. Fac. Agric. Kagoshima Univ. 12*: 107-58.
17. Sahrawat, K. L. (1974). Effect of pesticides on nitrification. *Pesticides* 8 (12): 30-33.
18. Sahrawat, K.L. (1975). Effect of pesticides on nitrogen fixation. *Pesticides 9* (6): 21-3.
19. Singhal, J.P., Khan, S. and Gupta, S.K. (1975). Effect of DD mixture on availability of some plant nutrients in a black cotton soil. *J. Indian Soc. Soil Sci. 23*: 109-12.
20. Srivastava, S.C. (1966). Effect of Telodrin on nitrification of ammonia in soil and its significance on nitrogen nutrition of sugarcane. *Pl. Soil 25*: 471-73.
21. Starkey, R. L. and Waksman, S.A. (1923a). Parial sterilization of the soil, microbiological activities and soil fertility. *II Soil Sci. 16*: 247-268.
22. Starkey, R.L. and Waksman, S.A. (123b). Partial soil, microbiological activities and soil fertility. III. *Soil Sci. 16*: 343-57.
23. Steenbjerg, F., Larsen, I., Jensen, I. and Bille, S. (1972). The effect of nitrogen and simazine on the dry matter yield and amino acid content of oats and on the absorption and utilization of various plant nutrients. *Pl. Soil 36*: 475-96.
24. Thakre, S. K. and Saxena, S. N. (1972). Effect of chlorinated insecticides on plant growth and uptake of nutrients by wheat and maize. *J. Indian Soc. Soil Sci. 20*: 45-8.
25. Tsvetkova, S.D. (1966). The action of simazine and atrazine on agrochemical properties of soils. *Soils Fert. Abstr.* 1967, *30*: 3301.
26. Varade, P.A. and Balial, D.K. (1969). Effect of some common insecticides on the availability of plant nutrients in black cotton soil. *J. Indian Soc. Soil Sci. 17*: 255.
27. Vicario, B.T. (1972). A study of the effect of pesticides on the phosphorus, calcium and total nitrogen levels in Novaliches clay loam soil. *Araneta Res. J. 19*: 103-04.
28. Waksman, S.A. and Starkey, R.L. (1923). Partial sterilization of soil, microbiological activities and soil fertility. I. *Soil Sci. 10*: 137-57.
29. Wilhelm, S. (1966), Chemical treatments and inoculum potential of soil. *Ann. Rev. Phytopath. 4*: 53-78. □