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Chavan AS
Department of Agronomy, College of Agriculture, Kharpudi, Jalna, Maharashtra, India

Kale AS
Department of Agronomy, College of Agriculture, Kharpudi, Jalna, Maharashtra, India

RE Kamble
Department of Agronomy, College of Agriculture, Kharpudi, Jalna, Maharashtra, India

Corresponding Author:
Chavan AS
Department of Agronomy, College of Agriculture, Kharpudi, Jalna, Maharashtra, India

Pesticide residues and their microbial degradation in soil: A review

Chavan AS, Kale AS and RE Kamble

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Abstract
Pesticides have been found a proven tool for the effective protection and improvement of the quality and quantity of food commodities. The extensive and indiscriminate use of these chemical compounds has created soil and plant health problems as well as water pollution problems which is unlikely to decrease in near future. Although, there is growing awareness among the consumers, farmers and scientific fraternity to the long lasting ill effects of these chemicals. Therefore, scientists are trying to develop the naturally benign chemicals which are eco-friendly and economically viable for plant protection. A practical solution of several approaches is to dissipate these chemicals from the environment through microbial decomposition. Micro-organisms in natural systems such as agricultural soils, water bodies and other environmental compartments are the important agents for degradation of pesticides. Results indicated that Bacteria and fungi are main the microbes involved in the degradation of different pesticides in soils. Specific group of bacteria and fungi are degrading specific group of pesticides. Soil properties (pH, temperature, water content & texture) affect the microbial degradation of different pesticides.

Keywords: Pesticide residues, microorganisms, soil

Introduction
Microbial degradation is one of the major processes of decomposition of herbicides in soil. The rate at which breakdown occurs depends on environmental conditions as well as inherent nature of herbicide. Generally warm and moist conditions favour microbial activity and hence the breakdown of herbicides. Some herbicides less only for a short time (eg. glyphosate), while others can persist for longer even more than one cropping season/year. Microorganisms decompose herbicide initially at a slow rate as detected by slow release of CO_2 from soil. It is called “lag phase” and in this phase they increase their population rapidly and build up intracellular or extracellular enzyme potential. Lag phase is later followed by rapid increase in the rate of CO_2 evolution which indicates rapid microbial activity.

Due to shift of rural population to the urban areas, use of herbicides has become a widespread practice, in order to combat the weed situations. Despite their usefulness in the increment of food production, their extensive use has led to the presence of residues in food and environmental contamination. The World Health Organization (WHO) data show that only 2-3% of applied chemical pesticides are effectively used for preventing, controlling and killing pests, while the rest remains in soil (EPA, 2005). The ultimate “sink” of the pesticides applied in agriculture care in soil. Therefore, the surface soil containing residual pesticides cause toxicity in the surrounding environment. Real and perceived concerns about pesticide toxicity have promoted their strict regulation in order to protect human health and to support the compliance and enforcement of laws and regulations pertaining to food safety. At present, the pesticide waste in being treated by physico-chemical methods which are not efficient and effective. Among biological approaches, the use of microbes/consortia with degradative ability is considered the most efficient and cost effective option to clean herbicide contaminated sites.

Soil being the store house of multitudes of microbes, in quantity and quality, receives the chemicals in various forms and acts as scavenger of harmful substances. The efficiency and the competence to handle the chemicals vary with the soil and its physical, chemical and biological properties.

Microorganisms play an essential role in the bioconversion and total breakdown of pesticides in the environment. Bioremediation is the breakdown (Biodegradation) of contaminationg compounds using microorganisms. These microbes often use contaminants as food source, thereby completely eliminating toxic compounds by changing them into basic elements such as carbon dioxide and water, a process known as mineralization. Incomplete degradation may also occur, or the partial breakdown of the original contaminant to a less complex form. Another result may be the transformation of a compound to a different chemical structure that may affect the toxicity and mobility of the original agent. Sometimes immobilization of a compound occurs where the agent overcome by the microbe but not eliminated or altered, which is often a potential benefit but rarely a final solution.

Microbial degradation of persistent herbicides like pendimethalin, atrazine (Singh *et al*. 2007) [20], fluchloralin (Singh and Kulshrestha, 1995) [19], metalachlor and alachlor (Maisnam *et al*., 2009) was studied and potential microbes isolated for their rapid degradation. Similar studies are carried out with a persistant insecticide bifenthrin (Sharma *et al*., 2012) [12] and five different PAHs (Choudhary *et al*. 2011) [3]. In one of the recent studies a bio-surfactant producing bacteria was used as an additional amendment which itself was a slow degrader but helped in solubilizing the low water soluble pesticide and made it available for degradation.

Bacterial degradation

Patil *et al.* (1970) [14] reported that most of microbial cultural out of 16 which were capable of degrading the dieldrin were also able to degrade endrin, DDT its metabolites and aldrin. Siddaramappa *et al.* (1973) [17] reported that incubation of flooded soil with *Pseudomonas* sp. for 20 hrs resulted in complete degradation of parathion. Revealed that the organism *Escherichia coli* degraded 10% of the added lindane in 12 days and approximately 1% of the consumed lindane appeared as pentachlorocyclohexane (PCCH) (Francis *et al.* (1975) [6]. Bourquin (1977) [2] reported that 13 isolates of bacteria isolated from salt marsh environment exhibited malathion degradation capability in the range of 1 to 90% when malathion was the sole source of 'C'. Yu *et al.* (2003) [23] found that degradation capability of wheat rhizosphere soil enhanced when it was inoculated with rhizospheric bacterial community designated as HD. Singh *et al*. (2004) [18] found that residues of chlorpyrifos when spiked at the rate of 25 mg L^{-1} was degraded rapidely in the soil inoculated with *Enterobacter* strain B-14 when applied at the rate 10^6 cells/g soil than in uninoculated soil. Jia *et al.* (2006) [9] observed that degradation of residues of monocrotophos when applied at the rate of 50 mg kg^{-1} when the soil was inoculated with *Paracoccus* sp. M-1 (@10^6 cfu g^{-1}) than uninoculated soil. Sorensen *et al.* (2008) [22] reported that consortium of *Variovorax* sp. SRS16 and *Arthrobacter globiformis* D47 mineralized the diuron in to $^{14}CO_2$ in the range of 31 to 33% from soil when spiked at the rate of 15.5 to 38.9 µg L^{-1}. Madhuban *et al.* (2008) [11] reported that cypermetherin was degraded by CS1 (*Pseudomonas stutzeri*) up to 66.8% in 20 days over control. The half-life of cypermethrin was found 20 days. Shivaramaiah (2010) [16] recorded almost 50% degradation of alpha and beta endosulfan in 12 hrs and complete degradation was observed within 48 hrs with a simultaneous increase in bacterial biomass. The degradation of endosulfan by *anabaena* sp. ATCC 7210 may provide the basis for development of bioremediation strategies to remediate pollutants in the environment. Madhuban *et al.* (2011) [10] reported that inoculation of *Burkholderia cepacia* strain CH9 at the rate of 50 µg ml^{-1} resulted 69% and 86% degradation of imidacloprid and metribuzin in 20 days, respectively. Mohamed *et al.* (2011) [13] found that incubation of soil at 40 °C for 45 days provided comparatively higher degradation of oxyfluorfen herbicide with respect to incubation to 28 °C. They also recorded the highest oxyfluorfen degradation with *Bacillus* sp. (80-95.6%) followed by *Pseudomonas* sp., *Arthrobacter* sp. (82.2%), *Aspergillus* sp. (77.8%), *Mycobacterium* sp. (75.6%), *Micrococcus* sp. (73.3%) and *Streptomyces* sp. (68.9%). Chowdhury *et al*. (2014) [4] reported that pyrazosulfuron (25 g/ha) was found safe to its effect on soil microbes as it completely degraded before 50 DAS.

Fungal degradation

Gupta *et al.* (2012) [7] showed that the optimum temperature for the growth and carbofuran degradation for *Aspergillus flavus*, *Aspergillus nidulans* and *Aspergillus Niger* was found 27 ºC. At pH 8.0 the biomass of all the three isolated strains was maximum and *Aspergillus Niger* showed almost complete degradation within 6 days after pesticide addition. On the contarary, *Aspergillus flavus* and *A. nidulans* showed significantly lesser carbofuran degrading ability of 96.2% and 95.1% at 9 and 10 days after pesticide addition, respectively. Jain *et al.* (2012) [7] observed that *Aspergillus Niger* sp. MCP1 grew optimally at pH 8.0 and 150 mg L^{-1} concentration of monocrotophos in a period of 10 days incubation. They also observed that *Aspergillus Niger (*MCP1) is capable of degrading 90% of monocrotophos under optimized condition in 10 days. Alrahman *et al.* (2013) [1] reported that *Trichoderma viride* had the highest degradation rate (97.6% butachlor reduction in 15 days) followed by *Pseudomonas* sp. (94.7% reduction in 21 days) and concluded that these organisms can be used for butachlor degradation. Biofenthrin pesticide is degraded by using consortium use of *Aspergillus Niger*, *Aspergillus flavus* and *Achaetomium strumarium* and degradation life of biofenthrin in soil could be reduced to 27.4 days (Singh *et al*., 2014) [21].

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