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Phosphate-solubility and phosphatase activity in Gangetic alluvial soil as influenced by organophosphate insecticide residues

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ABSTRACT

An experiment was conducted under laboratory conditions to investigate the effect of four organophosphate insecticides, viz. monocrotophos, profenophos, quinalphos and triazophos at their field application rates (0.75, 1.0, 0.5 and 0.6 kg a.i. ha^{-1}, respectively), on the growth and activities of phosphate solubilizing microorganisms in relation to availability of insoluble phosphates in the Gangetic alluvial soil of West Bengal, India. The proliferation of phosphate solubilizing microorganisms was highly induced with profenophos (38.3%), while monocrotophos exerted maximum stimulation (20.8%) towards the solubility of insoluble phosphates in soil. The phosphatase activities of the soil (both acid phosphatase and alkaline phosphatase) were significantly increased due to the incorporation of the insecticides in general, and the augmentation was more pronounced with quinalphos (43.1%) followed by profenophos (27.6%) for acid phosphatase, and with monocrotophos (25.2%) followed by profenophos (16.1%) for alkaline phosphatase activity in soil. The total phosphorus was highly retained by triazophos (19.9%) followed by monocrotophos (16.5%), while incorporation of triazophos and quinalphos manifested greater availability of water soluble phosphorus in soil.

1. Introduction

Autochthonous microorganisms govern the biological equilibrium of the soil ecosystem (Zhou et al., 2011) through their vital roles in the soil processes like nutrient cycling, soil aggregation and degradation of agrochemicals (Gil et al., 2011; Lupwayi et al., 2012). The presence of xenobiotic substances like pesticides due to agricultural practice in crop fields influence the composition of soil microbial community structure (Widmer et al., 2006) through the modulation of their metabolism (Singh and Walker, 2006). It is reported (Pimentel, 1995) that about 99.9% of the applied pesticides in the farmlands are released to the environment creating harm to the non-target organisms and cause a shift in the soil microbial community (Tortella et al., 2013) leading to the disturbance in the existing equilibrium of the soil ecosystem (Chen et al., 2015). In India, pesticide consumption has been increased by 41% during the period of 2005–2013 (MOA, 2013)[1] to combat insect pests for better crop growth. After reaching to the soil, pesticides are degraded by biotic and abiotic pathways; of which biodegradation is considered to be the most important and primary mechanism (Ortiz-Hernández and Sánchez-Salinas, 2010).

Microorganisms are scavengers in soil and degrade a great variety of chemical substances including the incorporated pesticides to derive carbon, energy and other nutrients for their growth and metabolism (Ohshiro et al., 1996). Enzymatic activities in soil are the most sensitive and appropriate indicators of soil physico-chemical characters (Amador et al., 1997) and microbial community structure (Kourtev et al., 2002). Microbial dissipation of the applied compounds starts with the release of specific enzymes by the soil microorganisms resulting in an increase in the activities of insecticide-utilizers (Jana et al., 1998) excepting for those species performing co-metabolism (Bollag and Liu, 1990), while other players are awaiting for their turn to come. As a result, insecticides and their derivatives in soil may stimulate (Das and Mukherjee, 1994) or decrease (Monkiedje and Spiteller, 2002) or keep unchanged (Cáceres et al., 2009) the microbiological activities leading to unpredictable amplification (Jana et al., 1998) or reduction of plant nutrients availability or maintain at par untreated control soil (Sardar and Kole, 2005).

By virtue of short to medium persistence (Albanis et al., 1998), high effectiveness (Laws, 2000) and broad-spectrum characteristics, organophosphate insecticides are being used increasingly throughout the world, especially in India. Multidimensional effects including shifts in bacterial and fungal counts (Pandey and Singh, 2004) and varied effects on soil enzymes (Singh and Singh, 2005) have been reported due to the application of different organophosphate insecticides in soil. The extracellular soil enzymes,

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[1] MOA: Ministry of Agriculture, Govt. of India.

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phosphomonoesterases (acid and alkaline phosphatases) play an important role in solubilizing insoluble phosphate monoesters (Sparling et al., 1986) and reflect soil biological health (Martinez-Salgado et al., 2010) after pesticide application. Phosphorus is an important metabolic and structural constituent as well as energy transforming element of soil microflora and crop plants. Effect of organophosphate insecticides on the phosphatase enzyme, biological transformation of the element in soil and ultimately on its availability to plants is of paramount significance so far as productivity of crops is concerned.

The objectives of the present study were to investigate the effect of four commonly used organophosphate insecticides viz., monocrotophos [Dimethyl (*E*)-1-methyl-2-(methylcarbamoyl) vinyl phosphate-a systemic broad spectrum insecticide used to control a variety of sucking, chewing and boring type of insects in a number of crops], profenophos [*O*-(4-Bromo-2-chlorophenyl) *O*-ethyl *S*-propyl phosphorothioate – a non-systemic insecticide used mainly in cotton and some other crops to control insect pests particularly of the order Lepidoptera], quinalphos [*O*, *O*-Diethyl *O*-2-quinoxalinyl phosphorothioate – a systemic insecticide used mainly in cotton and some other crops to control insect pests of the orders Lepidoptera, Coleoptera, Diptera and Hemiptera] and triazophos [*O*, *O*-Diethyl *O*-(1-phenyl-1*H*-1, 2, 4-triazol-3-yl) phosphorothioate – a non-systemic broad spectrum insecticide used to control a variety of sucking, chewing and boring type of insects in a number of crops including vegetables and fruit trees] (Fig. 1) at their recommended field application rates on the mobilization and solubility of insoluble phosphates as influenced by the enzymatic (phosphatase) activities of the phosphate solubilizing microorganisms in the Gangetic alluvial soil of West Bengal, India.

2. Materials and methods

2.1. Experimental methods

An experiment has been conducted under laboratory conditions with the Gangetic alluvial soil collected from the Experimental Farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India by taking several thin slices from the surface soil layer (0–15 cm) by means of a spade as outlined by Jackson (2014). The composite soil samples were air dried at 30–35 °C in shade and passed through a 2 mm (4–8 mesh cm^{-1}) sieve. The processed soils were stored in a screw-cap jar and used for the experiment. The soil belongs to Typic Haplustept (USDA, 1975) having the general characteristics as presented in Table 1. Four organophosphate insecticides, viz. monocrotophos [36% emulsifiable concentrate (EC), product name: Monocil-Insecticides India Ltd.], profenophos [50% EC, product name: Curacron-Syngenta Ltd.], quinalphos [25% EC, product name: Ekalux-Syngenta Ltd.] and triazophos [40% EC, product name: Kargil 400l-Tropical Agrosystem India Ltd.], at their recommended field application rates [0.75, 1.0, 0.5 and 0.6 kg a.i. ha^{-1} or 0.375, 0.5, 0.25 and 0.3 mg a.i. kg^{-1} respectively, (considering 2×10^6 kg being the weight of air dried soil covering one hectare area with 15 cm soil depth)], were mixed thoroughly with 2 kg of air-dried and sieved soil (≤ 2 mm) through a dilution method using a volumetric technique and were placed in earthenware pots having a soil depth of 15 cm. Soil moisture was adjusted to 60% of water holding capacity of the soil and maintained throughout the experimental periods. The pots were kept covered with black polyethylene sheets to avoid photodegradation of insecticides and evaporation loss of water from soil surface and incubated in the dark at

Table 1
General characteristics of the soil used in the experiment.

Type of soil	Gangetic alluvial
Soil taxonomy (USDA, 1975)[a]	Typic Haplustept
Textural class	Clay loam
Sand (%)	16.9
Silt (%)	44.0
Clay (%)	39.1
Water holding capacity (%)	58.2
pH (1:2.5 w/v) in water	5.6
EC (dS m^{-1})	0.18
CEC [cmol (p^+) kg^{-1}]	19.2
Organic C (g kg^{-1})	7.3
Total N (g kg^{-1})	0.63
Available N (mg kg^{-1})	127.3
Total P (g kg^{-1})	1.62
Available P (mg kg^{-1})	19.5
Phosphate-solubilizing microorganisms (cfu $\times 10^5$ g^{-1})	30.3
Phosphate-solubilizing capacity (mg g^{-1})	1.46
Phosphatase activity (μg *p*-nitrophenol g^{-1} h^{-1})	
Acid phosphatase	394.3
Alkaline phosphatase	66.8
Origin	Mohanpur, West Bengal, India

cfu: colony-forming unit.
[a] USDA: United States Department of Agriculture.

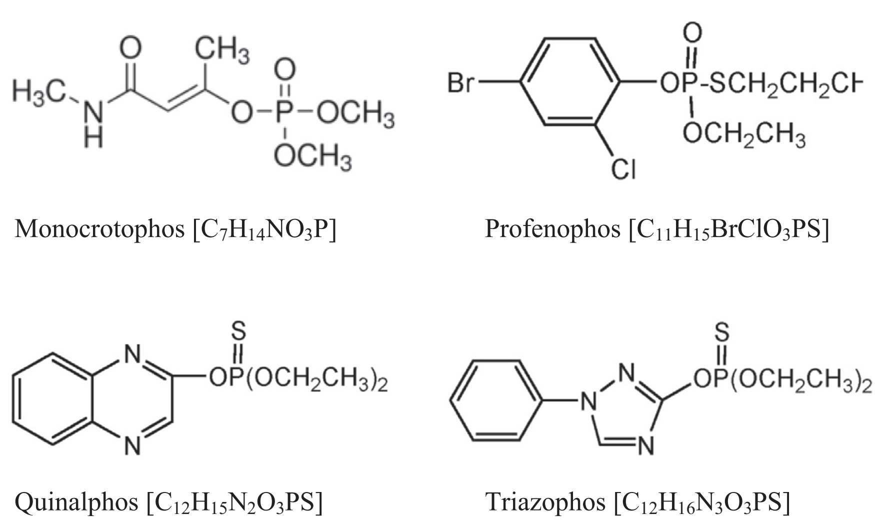

Fig. 1. The chemical structures of the insecticides used for the experiment.