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A comparison of effect of dimethoate and imidacloprid on soil respiration (carbon dioxide evolution from soil)

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Abstract

Several microorganisms, meso and macroorganisms have been reported for maintaining soil fertility. They are responsible for breakdown of organic matter and release of carbon dioxide, which is a measure of soil respiration, during their metabolic activities. But due to excessive use of agrochemicals, the populations of these beneficial microorganisms are declining which may decrease the fertility status of soil. Several studies were conducted on the toxic impact of some pesticides on soil respiration and reported that pesticides decreases or increases as well as have no effect on soil respiration. But no detailed study was conducted to find out the impact of imidacloprid and dimethoate, the commonly used pesticides in India, on soil respiration i.e. CO_2 evolution from soil under laboratory conditions. The experiment found that the CO_2 evolution drastically came down to 44.77% and 27.27% within 15 days of the application of dimethoate and imidacloprid respectively and gradually it recovered after 90 days. Two-way ANOVA indicates significant difference in soil respiration rate with respect to both doses of pesticides and days (F_1=15.94, F_2=10.71, $p<0.05$). One-way ANOVA shows significant difference between control and experimental sets up to 75 days ($F \geq 4.70$, $p<0.05$). LSD test reveals that significant difference among control, imidacloprid and dimethoate treated soils was only up to 30 days ($p<0.05$). This test further reveals that there was significant difference between control and dimethoate treated soil up to 75 days indicating that dimethoate is more toxic as compared to imidacloprid.

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Introduction

Microorganisms play an important role in maintaining the fertility of soil. They process around 90% of the energy bound in dead organic matter by the influence of intra-cellular and extra-cellular enzymes (Skujins, 1967). The CO_2 evolved during these metabolic activities (a measure of soil respiration) and the enzymes involved in around various decomposition and chemical transformation processes are therefore widely used as an indicator of biochemical activities in relation to soil contamination (Tu, 1993, Panda and Sahu, 2000; Pampulha and Oliveira, 2006; Tindaon *et al.*, 2011).

Many factors can have negative impacts upon soil health. These factors include loss of organic carbon (Islam and Weil, 2000), compaction (Singleto and Addison, 1999), disruption of soil macroaggregates (Islam and Weil, 2000), pesticides (Mitra and Raghu, 1998), pesticide breakdown products (Cernakova and Zemamovicova, 1998), inorganic pollution arising through fertilizers, fungicides and sludge application (Merry *et al.*, 1986, Gong *et al.*, 1997), fertilizers (Stamatiadis *et al.*, 1999) etc.

Varieties of agrochemicals (pesticides and fertilizers) are used indiscriminately over decades to boost the crop productivity. Pesticides more frequently used in rice fields of India are organophosphorous compounds like malathion, monocrotophos, dimethoate, quinolphos, phorate etc., organochlorine compounds like pretolachlor, butachlor etc., neonicotinoid compounds like clothianidin, thiamethoxam, imidacloprid etc. and carbamate compounds like carbofuran, carbendazim etc. Among these, dimethoate and imidacloprid are widely being used in the crop field of India due to their less toxicity and persistence.

Several studies were conducted about the effect of pesticides on soil respiration. Some of the studies indicated that pesticides have stimulatory effect on soil respiration (Parr and Smith, 1969; Karpiak and Iwanowaski, 1969; Robson and Gunner, 1970; Tu, 1970, 1972, 1973a,b, 1980; Atlas *et al.*, 1978; Bayer *et al.*, 1982) and some reported of having inhibitory effect (Bartha *et al.*, 1967; Bardiya and Gaur, 1968; Helweg, 1972) while some of the studies reported no effect on soil respiration (Bartha *et al.*, 1967; Bollen *et al.*, 1970; Salonius, 1972; Laveglia and Dahm, 1974; Davies and Marsh, 1977; Parker *et al.*, 1985; Martikainen *et al.*, 1998). There were also few reports which showed that pesticides initially inhibited but later stimulated the soil respiration (Domsch, 1970; Parr, 1974; Wainright, 1977) and few reports showed initial stimulation and later on inhibited soil respiration (Bayer *et al.*, 1982). However studies conducted by Ekelund *et al.* (1994), Ahtiainen *et al.* (2003) and Eisenhauser *et al.* (2009) recorded an inhibition of soil respiration while Bayer *et al.* (1982) reported stimulating effect and Martikainen *et al.* (1998) reported no effect due to dimethoate. On the other hand, Liu *et al.* (2001) reported little effect on soil respiration following imidacloprid application. However, no study was conducted to find out the effect of imidacloprid and dimethoate on the soil respiration in tropical country like India. Therefore, an experiment was undertaken with the following objectives:-

- To find out the effect of dimethoate and imidacloprid on soil respiration at recommended agricultural dose.
- To compare the toxicity between dimethoate and imidacloprid on the basis of soil respiration.

Materials and methods

Pesticide

Imidacloprid, Victor 17.8% SL, (Insecticide (India) Limited, Jammu) and Rogor 30% EC, the trade name of dimethoate, (Rallis India Limited, Mumabi) was used in the present work as the test chemicals. The chemical composition of imidacloprid is 1-(1-(6-chloro-2-pyridimy1) methy1)-N-nitro-2-imidazolidinimene and dimethoate is 0,0- dimethyl-S (N-methyl-carbamoylmethyl) dithiophosphate.

Soil

Soil was collected from an upland non-irrigated paddy field, which had no record of input of agrochemicals (fertilizers and pesticides). The soil had the following characteristics: laterite type, sandy loam texture, pH 6.8, organic matter (g%) 4.7, nitrogen (g%) 0.22 and a C/N ratio of 12.27. The soil was air dried and sieved before use.

Preparation of experimental set

Three sets of plastic culture pots each with thirty five replicates and two kg of soil were kept for control and recommended doses of imidacloprid and dimethoate. The recommended agricultural dose (mg a.i./ kg) for imidacloprid and dimethoate (0.05 and 0.4 respectively) was prepared in dilution of water and sprayed on to the soil surface. After evaporation of the solvent, enough water was added and the treated soil was thoroughly mixed for even distribution of the pesticide. However for control, only water was applied. The experiment was maintained at 20±2g% soil moisture and 25±2°C soil temperature. Out of thirty five replicates of each set, five replicates were taken at 15 days intervals up to 105 days to assess the effect of pesticides on soil metabolic activities.

CO_2 evolution from soil (Soil respiration)

Measurement of carbon-dioxide evolution from the soil was conducted following method of Witkamp (1966). Soil was kept in cylindrical jars. Inside the jar, a known strength of KOH solution was kept in a beaker and was made air tight. The control was run without soil. After a specific period barium chloride solution was added in the beaker containing KOH which resulted in a white precipitate of $BaCO_3$. The residual KOH was titrated with equivalent strength of HCl using phenolphthalein indicator. The value was expressed in terms of mg CO_2 evolved /kg/h.

$$CO_2 \text{ evolved from the soil in mg/kg/hr} = \frac{v \times 2.2}{\text{Hr X kg}}$$

Where, v = Difference between volume of HCL consumed in control and experimental set and Hr. = Time in hour.

Results

Soil respiration (CO_2 evolution) decreased following application of dimethoate and imidacloprid in soil up to a period of 90 days and then it recovered in pesticides treated soil (Figure-1). It shows a marked variation in CO_2 evolution among control, dimethoate and imidacloprid.

Table 1. CO_2 evolution (mg CO_2/kg dry soil/h±SD) following application of recommended agricultural doses of pesticides to soil.

Days	Control	Imidaclopid	Dimethoate	One-way ANOVA (F)	LSD (p<0.05)	One-way ANOVA
0	16.7±1.03	16.9±1.03	16.9±1.03	-	-	F1=15.94*
15	17.6±1.88a	12.8±1.03b (-27.27%)	9.72±1.0c (-44.77%)	33.47*	2.11	F2=10.71*
30	19.3±1.53a	14.85±1.82b (-23.06%)	12.1±1.38c (-37.31%)	20.90*	2.45	
45	21.5±1.32a	17.7±1.01a (-17.67%)	15.48±4.04b (-28.00%)	5.79*	3.9	
60	23.1±1.13a	20±0.42a (-13.42%)	18.06±3.68b (-21.82%)	5.18*	3.45	
75	22.8±1.04a	20.2±0.58a (-11.40%)	18.41±3.32b (-19.25%)	4.70*	3.15	
90	20.7±0.99a	20.3±6.73a (-1.93%)	19.39±2.04a (-6.33%)	0.11	6.32	
105	20.1±0.78	20.5±7.35 (1.99%)	20.2±1.96 (0.50%)	0.01	6.8	

* p<0.05, F1=between pesticides, F2= between days

Values in the same row with different alphabets are significantly different by LSD

Soil respiration (CO_2 evolution) drastically reduced by 44.77% and 27.27% in comparison to control set within 15 days after application of dimethoate and imidacloprid. But it gradually recovered after 90 days (Figure-2). This clearly indicates that both the pesticides have inhibitory effect on the soil respiration. It is also indicates that dimethoate is more toxic than imidacloprid in terms of soil respiration.

Two-way ANOVA indicates significant difference in soil respiration rate with respect to both doses of pesticides and days ($F1=15.94$, $F2=10.71$, $p<0.05$). Segmental analysis by one-way ANOVA shows significant difference between control and experimental sets up to 75 days ($F \geq 4.70$, $p<0.05$). LSD test reveals that significant difference among control, imidacloprid and dimethoate treated soils was only up to 30 days ($p<0.05$). This test further reveals that there was significant difference between control and dimethoate treated soil up to 75 days indicating that dimethoate is more toxic as compared to imidacloprid (Table-1).

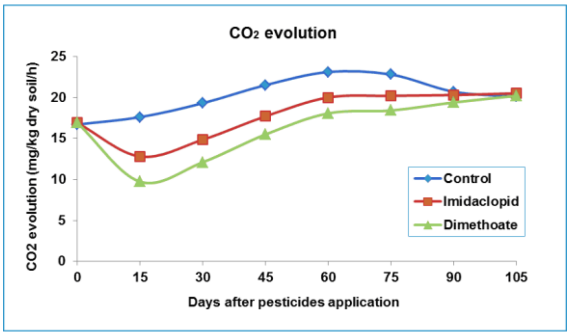

Fig. 1. Degree of Soil Respiration with respect to application of imidacloprid, dimethoate and control over a period of 105 days.

Discussion

Our experiment clearly showed inhibition in CO_2 evolution following application of recommended agricultural doses of imidacloprid and dimethoate to soil. The significant decline in CO_2 evolution continued up to 75 days in both the pesticide treated soils. Further, as revealed from LSD test, dimethoate is more toxic compared to imidacloprid. Similar results also reported for dimethoate and imidacloprid by few earlier studies. Ekelund *et al.* (1994) stated that soil respiration was significantly affected for about 10 days following dimethoate application. Ahtiainen *et al.* (2003) reported reduction of soil respiration on applying higher concentration of dimethoate. Eisenhauser *et al.* (2009) found that dimethoate declined soil respiration to some extent. Similarly Liu *et al.* (2001) reported little effect on soil respiration following imidacloprid application.

Depression in respiratory activity with pesticide treatment has also been reported by several workers. Chandra *et al.* (1960) found that herbicides like TCA, EPTC, diuron and simazine depresses soil respiration temporarily in nine widely different soils. Kulinska (1967) and Eno (1972) reported that higher rate of simazine inhibits soil respiration although field rate of simazine showed no appreciable effect on CO_2 evolution (Coke and Robinson, 1960). Retardation of CO_2 evolution in clay and loam soil treated with BHC at five times of the recommended field rate was reported by MacRae *et al.* (1967). They concluded that this type of retardation might be due to the inhibitory effect of BHC on mineralization of native organic matter. Bartha *et al.* (1967) reported that the application of carbamate insecticides inhibits CO_2 evolution. They also reported that the depression of CO_2 evolution following application of malathion, parathion and phorate was occurred only after initial stimulation for a brief period. Bardiya and Gaur (1968) reported that under laboratory conditions lindane at 100 ppm depressed CO_2 evolution after three days while dieldrin at 100 ppm decreased CO_2 evolution from the first day. Helweg (1972) observed that CO_2 liberation was reduced for a short time by 50 and 100 ppm of chlorthiamid but not by 10 and 100 ppm of dichlobenil. Balasubramaniyan and Narayayan (1980) revealed that aldicarb, disulfoton and fenitrothion at field rate levels (5 ppm) and at double the rate depressed respiratory activity of soil microorganisms. Yao *et al.* (2006) reported that acetamiprid a neonicotinoid, at normal field dose can pose a certain potential threat to soil respiration.

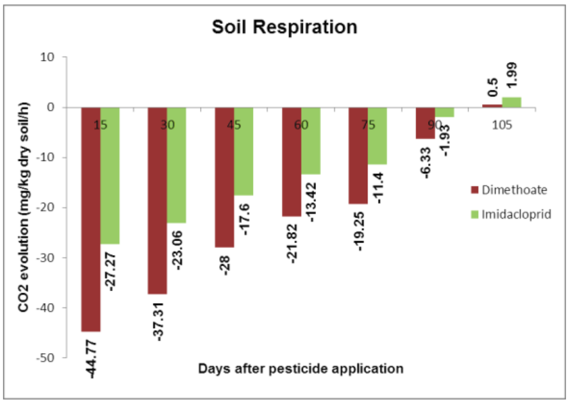

Fig. 2. Degree of Soil Respiration after application of dimethoate and imidacloprid in comparison to control set.

Domsch (1970) reported that fungicide treatment often leads an initial decrease in soil respiration followed by marked stimulation. Wide spectrum fungicides and fumigants have marked inhibitory effect on soil respiration followed by stimulatory effect (Parr, 1974; Wainright, 1977). Gupta *et al.* (1975) reported that baygon at 25 and 125 ppm depressed CO_2 evolution for 10 days followed by recovery in activity. On the other hand, Bayer *et al.* (1982) observed that baygon (propoxur), lindane, endrin, parathion, methidation and omethoate stimulated CO_2 evolution up to 5 weeks after treatment, and then a distinct decrease in activity was noticed.

Bartha *et al.* (1967) suggested that the mechanism responsible for change in soil microbial respiration might be the combination of following: an insecticide acting to uncouple oxidation phosphorylation or an insecticide with selective toxicity inhibiting CO_2 production of some micro-organism but is oxidized by other microbes that are resistant to its initial action. They concluded that pesticide concentration in excess of those recommended for agriculture use can produce an effect on soil microbial respiration and soil with organic matter can reduce pesticide toxicity and can increase microbial degradation of the pesticide in soil. Other factors like pH, soil moisture, organic matter content, variation in climatic factors etc. also influence the soil metabolic activity (Ross and Roberts, 1970; Yao *et al.*, 2006).

The present investigation indicated that the soil respiration (CO_2 evolution) was affected by both the pesticides even in their recommended agricultural doses. If soil respiration is hampered then it would affect the soil fertility. It is also seen that dimethoate is more toxic but imidacloprid has also some threats to soil respiration too. So it is suggested that these pesticides should be used in their recommended doses and only once to protect the soil health.

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