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Available Nitrogen and Arginine Deaminase Activity in Groundnut (*Arachis hypogaea* L.) Fields after Imidacloprid, Diazinon, and Lindane Treatments

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Plant available nitrogen and arginine deaminase activities were determined in insecticide-treated groundnut (*Arachis hypogaea* L.) fields between July and November for three consecutive years (1997−1999). Diazinon was applied for both seed and soil treatments. However, imidacloprid and lindane were used only for the seed treatments. An average half-life ($t_{1/2}$) of diazinon in seed- and soil-treated fields was 29.32 and 34.87 days, respectively. Its residues were detected till 60 days in both seed- and soil-treated fields. Diazinon treatments had shown stimulatory effects on available nitrogen in both types of treatments. However, the increase in arginine deaminase activity was only observed in diazinon soil-treated field. Residues of imidacloprid and lindane were detected in seed-treated fields till 90 and 120 days with an average half-life ($t_{1/2}$) of 40.96 and 53.39 days, respectively. Imidacloprid had stimulatory effects, and lindane had adverse effects on both available nitrogen and arginine deaminase activities.

KEYWORDS: Available nitrogen; soil enzyme; arginine deaminase; imidacloprid; diazinon; lindane

INTRODUCTION

Insecticides are widely used in agriculture as various formulations to control the insect pests. No matter how and where these insecticides are applied, it finally reaches the soil and may affect the soil microbes and their biochemcal activities (*1*−*3*). Both microbes and plants release the major amount of enzymes in the soil. Soil contains free enzymes, immobalized extracellular enzymes, and enzymes within microbial cells. Soil microbes and enzymes are responsible for maintaining the soil fertility through degradation and mineralization of organic matter including plant and animal residues. Any alteration in microbial population and their biochemical activities may indirectly affect the soil enzyme activities and plant available nutrients. Therefore, soil enzyme activities can be used as an indicator of the microbial biomass (*4*). It is reported that arginine ammonification has a significant correlation to soil microbial biomass and biochemical activites (*5*, *6*). To study the impact of insecticide usage on different soil functions, the experiments were conducted in groundnut soils.

Groundnut ranks seventh among crops in terms of insecticide consumption in India (*7*). Insecticides such as imidacloprid, diazinon, and lindane are generally used against white grubs (*Holotrichia consanguinea*) in groundnut fields. The present investigations were carried out to determine the effects of diazinon, imidacloprid, and lindane treatments at their recommended rates on plant available nitrogen and arginine deaminase activities in groundnut fields.

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MATERIALS AND METHODS

Experimental Field. Experiments were conducted at the Agricultural Research Station, Durgapura, Jaipur, India (latitude 26.55°N, longitude 75.52°E, and 390 m above the sea level) in the second week of July and continued till the last week of November or till harvest in all three consecutive years (1997−1999). Groundnut variety MA 10 at 80 kg ha^{-1} was sown at approximately 50 cm row to row and 25−30 cm plant to plant spacing. Diazinon was applied for both seed and soil treatments. However, imidacloprid and lindane were used only for seed treatments. The insecticides were applied in seed treatments as seed dressings at the time of sowing, and in soil treatments, the furrows were treated as drenching with diazinon after 15 days of sowing. There were three plots (5×8 m^2) for each treatment, which were separated by the ridges. These plots were a part of a groundnut field of about 5 hectares. The total number of experimental plots was 15 including three control plots of the same size. The selected plots were first time treated with the insecticides. The schedule of insecticide treatment and cultivation for all plots was the same for all three years (1997−1999).

Insecticides were obtained from local pesticide industries. Diazinon 20 E. C. (Knox out) was from Novartis (Sandoz), imidacloprid 70 WS (Confidor) was from Bayer, and lindane 20 E. C. (Kanodane) was from Canoria Chemicals. The recommended rates for seed treatment were 5 g a.i. kg^{-1} seed for diazinon, 2.8 g a.i. kg^{-1} seed for imidacloprid, and 10 g a.i. kg^{-1} seed for lindane. For soil treatment, diazinon was applied at 800 g a.i. ha^{-1}.

Soil Sampling. Soil samples were collected randomly at five places from the depth of 0−12 cm near the rhizosphere zone using a trowel and mixed thoroughly to prepare one homogeneous composite sample. The samples were cleaned by removing plant material and other debris by sieving through 4 mm mesh. The final weight of each composite sample was approximately 2 kg. There were three composite replicates for all of the treatments, i.e., T_1R_1, T_1R_2, and T_1R_3 for diazinon seed treatment (where T is for treatment and R is for replicate); T_2R_1, T_2R_2,

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and T_2R_3 for diazinon soil treatment; T_3R_1, T_3R_2, and T_3R_3 for imidacloprid seed treatment; and T_4R_1, T_4R_2, and T_4R_3 for lindane seed treatment. Sampling from control (untreated) plots was also done in triplicates. Samples were taken on 0, 1, and 15 days and then regularly after every 30 days from the date of sowing till harvest. Sampling schedules were the same for all three years. Samples were brought to the laboratory in an icebox and stored in the deep freezer at −20 °C for soil available nutrients analysis. Insecticide residues and enzyme activities were determined immediately.

Diazinon Residue Analysis. Twenty five gram soil samples in triplicate were extracted with a 40 mL mixture of acetone:methanol (1:1, v/v) in a conical flask by shaking for 3 h at 150 rpm on a mechanical shaker. This extract was then filtered, and the soil was washed thrice with 20 mL of the same mixture. The extract was transferred to a separatory funnel and diluted with 25 mL of double-distilled water partitioned with an equal volume of benzene. The benzene layer was withdrawn, and the partitioning procedure was repeated thrice. The benzene was passed through an anhydrous Na_2SO_4-packed column (50 cm × 15 mm i.d.) and concentrated by a rotary vacuum evaporator. The residues were dissolved in 5 mL of gas−liquid chromatography (GLC) grade hexane and filtered through a nylon membrane filter and finally dried in a speed vacuum concentrator. Then, it was diluted in 1 mL of hexane for GLC analysis. Diazinon residues were assayed by GLC Hewlett-Packard model 5890 series II equipped with a packed column (3% OV-101, 6 m × 2 mm i.d.) and flame photometric detector. The operating conditions were as follows: nitrogen (carrier gas) flow rate, 60 mL min^{-1}; hydrogen, 20 mL^{-1}; air, 40 mL^{-1}; injector temperature, 230 °C; column temperature, 160−165 °C at 5 °C and then 220 °C; detector temperature, 240 °C. Under these conditions, the retention time for diazinon was 6.5 min. An average recovery of diazinon from spiked soil samples was 93 ± 4%. Using the same extraction method, 94−103% of extraction efficiencies have been reported for the diazinon in sandy loam soil (*8*).

Lindane Residue Analysis. Fifty grams of soil was extracted in a Soxhlet extractor for 24 h or approximately 65 cycles using hexane:acetone (1:1, v/v) mixture as the extracting solvent. The extract was passed through a Na_2SO_4 column, and the content was then concentrated by rotary vacuum evaporator to about 10 mL and was cleaned up by column chromatography.

The chromatographic columns (50 cm × 15 mm i.d.) were slurry packed with florisil (magnesium silicate, 7 g) over a layer of anhydrous Na_2SO_4 (1 cm). The column was washed with light petroleum distillate (60 mL, B. P. 60−80 °C fraction). Just prior to the exposure of the Na_2SO_4 layer to the air, the concentrated extract was poured onto the column and allowed to move down. The elution was carried out with different mixtures of light petroleum distillate + diethyl ether. Ratios of light petroleum distillate + diethyl ether mixtures were used as 100 + 0, 94 + 6, 85 + 15, 50 + 50, and 0 + 100 v/v, 100 mL in each case. The eluate after collection was evaporated to near dryness using a rotary vacuum evaporator, and the residues were dissolved in 2 mL of GC grade hexane for GLC analysis.

Lindane residues were assayed by GLC, ECD (Hewlett-Packard model 5890 series II), using a megabore column (HP-1, 10 m × 0.53 m, 2.65 μm film thickness). The operating conditions were as follows: nitrogen (carrier gas) flow rate, 40 mL min^{-1}; temperature injector, 250 °C; column, 180−220 °C at 5 °C; detector, 300−350 °C; injection volume, 3 μL. Under these conditions, the retention time for lindane was 3.8 min. The average recovery of lindane from spiked soil samples was found to be 94 ± 5%. Almost similar supporting results for recoveries of α-, β-, and γ-isomers of HCH were found in soil sediment samples, i.e., 95.0 ± 5.6, 93.0 ± 7.6, and 97.0 ± 6.6%, respectively (*9*).

Imidacloprid Residue Analysis. Thirty grams of soil was mixed with 50 mL of a acetonitrile:water (7:3, v/v) mixture in a polyethylene bottle and shaken for 3 h on a mechanical shaker at 150 rpm. The soil suspension was then filtered through Whatman filter paper no. 1. The soil was washed twice with 50 mL of an acetonitrile:water mixture and finally with 30 mL of pure acetonitrile. The filtrate was concentrated up to about 45 mL by a rotary vacuum evaporator and partitioned with dichloromethane. Dichloromethane fractions were collected and passed through a column (50 cm × 15 mm i.d.) packed with anhydrous Na_2SO_4 to remove traces of water. The extract was finally concentrated to near dryness by a rotary vacuum evaporator.

It was then diluted in 1 mL of acetonitrile and analyzed by high-performance liquid chromatography (HPLC) (Shimadzu chromatogram C-R3A) with an ultraviolet (UV) detector at 270 nm. The operating conditions were as follows: Lichrosorb RP-C_{18} (ODC) analytical column (25 cm length × 4 mm i.d.); oven temperature, 40 °C; mobile phase, acetonitrile:water 7:3, v/v; flow rate, 1.5 mL min^{-1}; injection volume, 25 μL. Under these conditions, the retention time for imidacloprid was 3.2 min. The recovery of imidacloprid from spiked samples was 96 ± 3%. However, recoveries for imidacloprid have been reported to be 93.37, 91.07, and 90.71% in sandy, sandy loam, and silty loam soils, respectively (*10*).

Table 1. Physicochemical Properties of the Soil at the Agricultural Research Station Durgapura, Jaipur, India

sand	59.65 ± 2.47%
silt	29.2 ± 1.38%
clay	8.13 ± 0.58%
pH	6.98–7.22
cation exchange capacity	4.5–5.8 μS
water holding capacity	22.23 ± 0.78%
organic matter	0.63–0.93 ± 0.04% g/air-dried soil
available nitrogen	110–155 mg kg/air-dried soil
available phosphorus	40.0–60.0 mg kg/air-dried soil

Arginine Deaminase Analysis. Five grams of moist soil samples in triplicate was incubated in test tubes at 37 °C for 3 h with 2 mL of L-arginine solution. Similarly, the blank was also prepared and immediately frozen at −20 °C. After incubation, 18 mL of KCL solution was added in both insecticide-treated samples and controls. Ammonium ions released by arginine deaminase activity were extracted with potassium chloride solution, shaken for 30 min, and then filtered. One milliliter of filtrate was extracted with 3 mL of KC1, 2 mL of sodium phenolate, and 1 mL of sodium nitroprusside solutions. A greenish blue color was formed due to idophenol reaction (*7*) after 30 min, and the density of color was determined by a Shimadzu spectrophotometer (C-R3A) against the blank at 630 nm.

Available Nitrogen Analysis. Ten grams of soil was mixed with 20 mL of distilled water in distillation flasks, and then, it was shaken well for 15−20 min on a mechanical shaker. One hundred milliliters of 0.32% potassium permanganate and 2.5% sodium hydroxide solutions was added. This content was distilled till the volume of the solution became around 30 mL in the collection flask. Liberated ammonia was estimated by collecting it in 2% boric acid containing a few drops of mixed indicator (0.066 g of methyl red and 0.099 g of bromocresol green dissolved in 100 mL of 95% ethanol). Titration was done against 0.02 N sulfuric acid solution. Blank correction without the soil was made to account for the nitrogen present in the chemicals as impurities.

Meteorological Conditions. The weekly maximum and minimum temperatures, relative humidity, and rainfall were recorded throughout the experimental periods. In 1997, the maximum temperature was 39.6 °C and the minimum temperature was 6.2 °C. Similar trends were observed for 1998 and 1999. The relative humidity ranged between 100 and 10% in all three experimental years. Rainfall was 80 mm in 1997, 83 mm in 1998, and low in 1999, i.e., 60.4 mm.

Statistical Analysis. Data obtained in triplicate from treated soils were used as raw data for randomized block design and analysis of variance. In each treatment, the variance was used to determine the significant effect of insecticides on available nitrogen and arginine deaminase activities. Correlation analysis was used to explore relationships among variables. Significance was defined as $p \leq 0.05$, and SAS statistical software was used for all analysis (Statistical Analysis Software Inc., 1990).

RESULTS AND DISCUSSION

The experimental soil was sandy loam (**Table 1**). No significant changes in soil properties were observed after insecticide treatment as compared to untreated (control) soil.

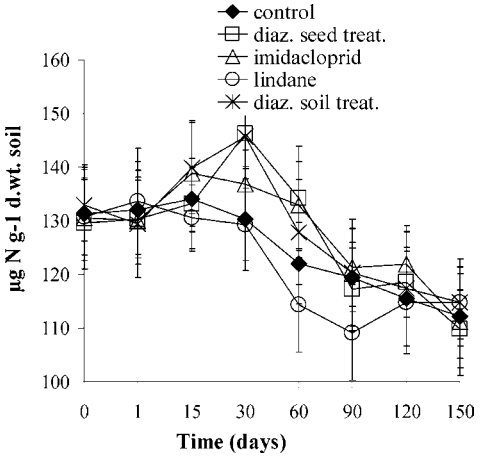

Figure 1. Available nitrogen (μg N g^{-1} dry wt soil) after diazinon, imidacloprid, and lindane treatments in a groundnut field at the Agricultural Research Station Durgapura, Jaipur, 1997.

Table 2. Diazinon Residues after Seed Treatment at the Agricultural Research Station Durgapura, Jaipur, India[a]

	diazinon residues (ηg/g dry wt soil)					
days	1997	dissipation (%)	1998	dissipation (%)	1999	dissipation (%)
0	ND		ND		ND	
1	12.32 ± 1.6	0.00	10.98 ± 1.4	0.00	16.22 ± 2.3	0.00
15	10.87 ± 2.2	11.77	9.67 ± 1.7	11.93	11.12 ± 1.6	31.44
30	7.33 ± 1.0	40.50	6.00 ± 2.0	45.36	8.69 ± 2.2	46.42
60	3.04 ± 1.9	75.32	2.36 ± 1.5	78.51	4.27 ± 1.4	73.67
90	ND		ND		ND	
120	ND		ND		ND	
150	ND		ND		ND	
$t_{1/2}$	29.7		27.0		31.1	
	average $t_{1/2} = 29.3$					

[a] Trial sown with treated seeds; ND, not detected.

Its effect on available nitrogen and argnine deaminase activities was studied for three consecutive years (1997−1999).

Diazinon Seed Treatment. In 1997, there was a 12.33% increase ($p \leq 0.05$) in plant available nitrogen in diazinon seed-treated fields after 30 days of sowing and it was continued till 60 days. In the 60th day sample, available nitrogen was 9.94% more ($p \leq 0.05$) in comparison to control fields (**Figure 1**). Samples from the 30th and 60th days contained 7.33 ± 1.0 and 3.04 ± 1.9 ηg/g dry wt soil diazinon residues (**Table 2**). However, no significant changes were found in arginine deaminase activities in 1997 (**Figure 4**). In 1998, an almost similar increase in plant available nitrogen was found in treated fields. An increase ($p \leq 0.05$) in available nitrogen was 9.72 and 5.75% in 15th and 30th day samples (**Figure 2**), and in these samples, 9.67 ± 1.7 and 6.0 ± 2.0 ηg/g dry wt soil residues of diazinon were found (**Table 2**). Similarly, no significant changes in arginine deaminase activities were also found in 1998 (**Figure 5**). The residues of diazinon for the experimental period ranged from 2.36 ± 1.5 to 10.98 ± 1.4 ηg/g dry wt soil (**Table 2**).

In 1999, similar results on plant available nitrogen were found in diazinon seed-treated fields. Dissipaton of diazinon residues was also almost similar to crop periods 1997 and 1998 (**Figure 3**). However, in comparison to crop periods 1997 and 1998, a significant ($p \leq 0.05$) increase of 18.8% in the arginine deaminase activity was observed in the 60th day treated sample (**Figure 6**).

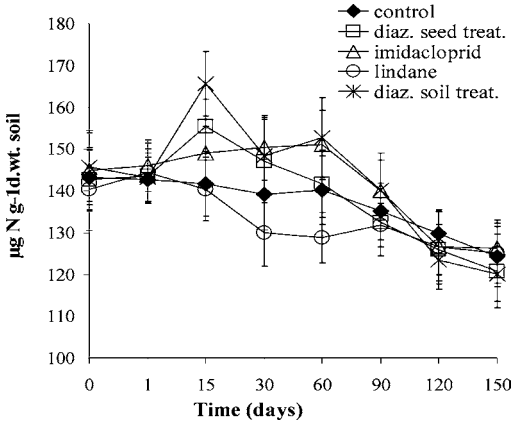

Figure 2. Available nitrogen (μg N g^{-1} dry wt soil) after diazinon, imidacloprid, and lindane treatments in a groundnut field at the Agricultural Research Station Durgapura, Jaipur, 1998.

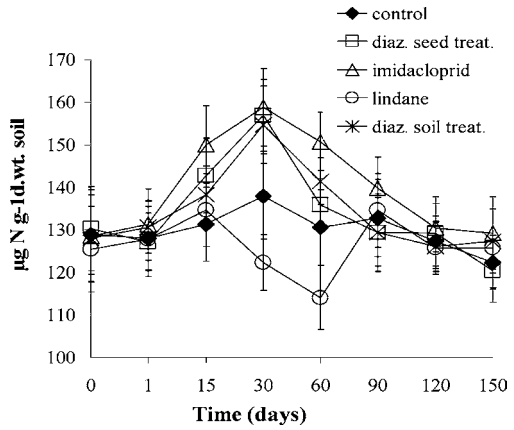

Figure 3. Available nitrogen (μg N g^{-1} dry wt soil) after diazinon, imidacloprid, and lindane treatments in a groundnut field at the Agricultural Research Station Durgapura, Jaipur, 1999.

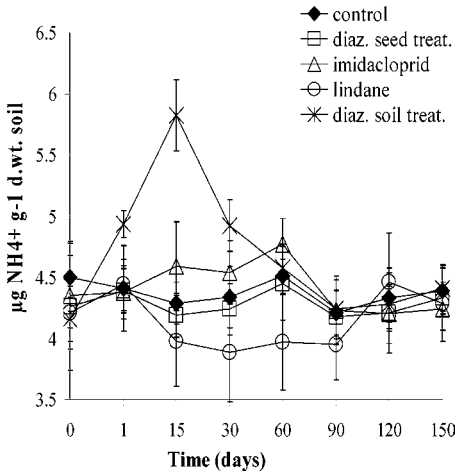

Figure 4. Arginine deaminase activity (μg NH_4^+ g^{-1} dry wt soil) after diazinon, imidacloprid, and lindane treatments in a groundnut field at the Agricultural Research Station Durgapura, Jaipur, 1997.

Diazinon Soil Treatment. In 1997, 26.71 and 11.85% increases ($p \leq 0.05$) in plant available nitrogen were found in 15th and 30th day samples of treated fields as cpmpared to control fields (**Figure 1**). Increases ($p \leq 0.05$) in arginine deaminase activity were also obseved, i.e., 35.67 and 13.37% in these samples (**Figure 4**). These samples contained 10.0 ± 1.2 and 9.64 ± 1.8 ηg/g dry wt soil diazinon residues, respectively (**Table 3**). In 1998, diazinon soil-treated fields

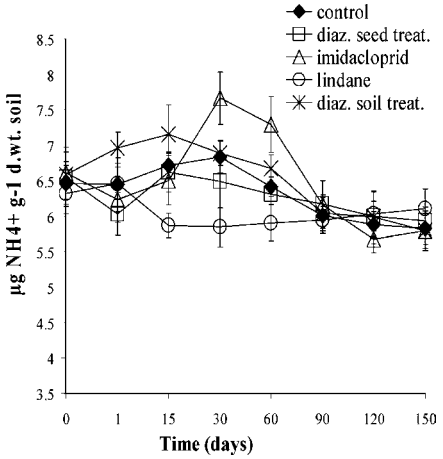

Figure 5. Arginine deaminase activity (μg NH_4^+ g^{-1} dry wt soil) after diazinon, imidacloprid, and lindane treatments in a groundnut field at the Agricultural Research Station Durgapura, Jaipur, 1998.

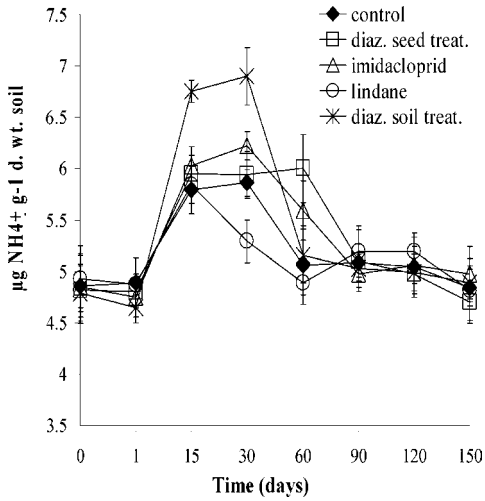

Figure 6. Arginine deaminase activity (μg NH_4^+ g^{-1} dry wt soil) after diazinon, imidacloprid, and lindane treatments in a groundnut field at the Agricultural Research Station Durgapura, Jaipur, 1999.

Table 3. Diazinon Residues after Soil Treatment at the Agricultural Research Station Durgapura, Jaipur, India[a]

	diazinon residues (ηg/g dry wt soil)					
days	1997	dissipation (%)	1998	dissipation (%)	1999	dissipation (%)
0	14.16 ± 2.1	0.00	20.00 ± 2.5	0.00	18.21 ± 3.2	0.00
1	12.70 ± 1.8	10.31	15.08 ± 1.9	24.60	13.62 ± 2.8	25.21
15	10.00 ± 1.2	29.38	6.84 ± 0.8	65.80	8.95 ± 2.4	50.85
30	9.64 ± 1.8	31.92	3.84 ± 0.6	80.80	4.22 ± 1.6	76.83
60	2.83 ± 0.3	80.01	2.00 ± 0.1	90.00	3.62 ± 1.5	80.12
90	ND		ND		ND	
120	ND		ND		ND	
150	ND		ND		ND	
$t_{1/2}$	38.7		27.0		38.6	
	average $t_{1/2}$ = 34.8					

[a] Trial of soil treatment in furrows as drenching; ND, not detected.

showed almost a similar trend on plant available nitrogen as well as arginine deaminase activities. Plant available nitrogen was increased ($p \leq 0.05$) by 16.90% in treated fields after 15 days. This trend was continued till 60 days. In 60th day samples, a 8.90% increase ($p \leq 0.05$) in plant available nitrogen was found (**Figure 2**), while an increase in enzyme activity was found to be 6.56% in the 15 day sample (**Figure 5**). During this period, residues varied from 6.84 ± 0.8 to 2.00 ± 0.1 ηg/g dry wt soil (**Table 3**).

Table 4. Imidacloprid Residues after Seed Treatment at the Agricultural Research Station Durgapura, Jaipur, India[a]

	imidaloprid residues (ηg/g dry wt soil)					
days	1997	dissipation (%)	1998	dissipation (%)	1999	dissipation (%)
0	ND		ND		ND	
1	48.21 ± 2.3	0.00	46.66 ± 3.6	0.00	40.66 ± 3.6	0.00
15	42.45 ± 3.1	11.95	39.28 ± 4.4	15.82	33.69 ± 5.1	17.14
30	30.09 ± 4.2	37.59	25.86 ± 2.2	44.58	27.15 ± 3.8	33.23
60	23.18 ± 2.1	51.92	17.01 ± 4.0	63.54	14.88 ± 2.7	63.40
90	9.98 ± 3.1	79.30	8.17 ± 3.3	82.49	10.91 ± 3.4	73.17
120	ND		ND		ND	
150	ND		ND		ND	
$t_{1/2}$	39.6		35.8		47.4	
	average $t_{1/2}$ = 40.9					

[a] Trial sown with treated seeds; ND, not detected.

Similar results for plant available nitrogen and arginine deaminase activities were observed in 1999 (**Figures 3** and **6**). An increase in plant available nitrogen was 5.27 and 12.21%, respectively, for 15th and 30th day samples (**Figure 3**). Similarly, 16.59 and 17.75% increases ($p \leq 0.05$) in arginine deaminase enzyme activity were found in these samples (**Figure 6**). During this period, 6.95 ± 2.4 and 4.22 ± 1.6 ηg/g dry wt soil diazinon residues were found (**Table 3**).

It has been observed that the diazinon in both seed and soil treatments had stimulatory effects on available nitrogen in the rhizosphere region between 15 and 60 days after sowing. Similarly, the stimulated ammonification ability of the microorganisms was reported for the sandy loam soil (*11*). An increased ammonification rate was also found in sandy loam soil after herbicides application (*12*). Significant mineralization of nitrogen was also reported after the insecticide application, which brought a considerable increase in the available nitrogen, and it remained more prominent up to 30 days, followed by a steady decline till 60 days (*13*, *14*).

It was observed that diazinon seed treatment had more or less no effect on arginine deaminase activity. However, diazinon soil treatment had a stimulatory effect. Similar results were also reported for chlorpyrifos (*15*) in clay soil (pH 5.3). Average half-lives of diazinon seed and soil treatments were 29.32 and 34.81 days, respectively, for all three experimental years. It was reported that diazinon had a low persistence in soil (*16*) and had a half-life of 2−4 weeks (*17*).

Imidacloprid Seed Treatment. A considerable increase ($p \leq 0.05$) in both plant available nitrogen as well as arginine deaminase activities was observed in imidacloprid seed-treated fields. In 1997, a 25.99% increase in available nitrogen was found after 15 days of sowing (**Figure 1**), while 7.0 and 5.8% increases in arginine deaminase activities were observed in 15th and 60th day samples, respectively (**Figure 4**). During that period, the imidacloprid residues were 42.45 ± 3.1 and 23.18 ± 2.1 ηg/g dry wt soil (**Table 4**). In 1998, the imidacloprid seed-treated field showed an almost similar pattern for plant available nitrogen, i.e., 8.10 and 7.70% increases ($p \leq 0.05$) in plant available nitrogen for 30th and 60th day samples, respectively (**Figure 2**). Similarly, 12.16 and 13.80% increases ($p \leq 0.05$) in arginine deaminase activities were found for these samples (**Figure 5**). During that period, imidacloprid residues ranged from 17.01 ± 4.0 to 25.86 ± 2.2 ηg/g dry wt soil (**Table 4**). In 1999, a significant increase in available nitrogen was observed after 15 days of treatment and this trend

Table 5. Lindane Residues after Seed Treatment at the Agricultural Research Station Durgapura, Jaipur, India[a]

	lindane residues (ηg/g dry wt soil)					
days	1997	dissipation (%)	1998	dissipation (%)	1999	dissipation (%)
0	ND		ND		ND	
1	51.12 ± 2.1	0.00	48.02 ± 2.3	0.00	55.01 ± 0.6	0.00
15	46.08 ± 3.2	9.86	43.73 ± 4.3	8.93	48.53 ± 5.1	11.78
30	38.33 ± 4.7	25.02	39.30 ± 3.5	18.16	41.83 ± 5.5	23.96
60	30.00 ± 2.1	41.31	31.34 ± 2.5	34.74	34.11 ± 3.7	38.00
90	16.00 ± 2.9	68.70	24.98 ± 1.9	47.98	28.87 ± 3.2	47.52
120	10.80 ± 1.4	78.87	9.67 ± 1.8	79.86	12.00 ± 2.0	78.19
150	ND		ND		ND	
$t_{1/2}$	53.5		51.9		54.6	
	average $t_{1/2}$ = 53.3					

[a] Trial sown with treated seeds; ND, not detected.

was continued till 60 days. In 15th and 60th day samples, 13.78 and 15.45% increases ($p \leq 0.05$) in available nitrogen were observed as compared to the control field (**Figure 3**). Likewise, an increase ($p \leq 0.05$) in arginine deaminase activity was also found in 15th and 60th day samples, i.e., 4.20 and 10.48%, respectively (**Figure 6**). In these samples, 33.67 ± 5.1 and 14.88 ± 2.7 ηg/g dry wt soil imidacloprid residues were detected (**Table 4**). Thus, it was found that imidacloprid seed treatment had a stimulatory effect on plant available nitrogen for all three years of experiments between 15 and 60 days after sowing. An increase in ammonification rates was also observed after pesticide treatments under field conditions (*18*−*20*). Insecticides probably induce the growth and activity of both ammonifyning and nitrifying microorganisms, which in turn released larger amounts of mineral nitrogen into the soil (*21*, *22*).

An increased enzyme activity was observed for all three experimental years between 15 and 60 days in imidacloprid seed-treated fields. Similarly, Hamady and Sholoa (*23*) evaluated the urease activity after imidacloprid seed treatement in Egyptian soil and observed that imidacloprid had no adverse effect on urease activity. In the present investigation, an average half-life of imidacloprid was 40.96 days. Scholz and Spiteller (*24*) also repoted a half-life of 48−190 days.

Lindane Seed Treatment. Lindane seed treatment had some adverse effects on both available nitrogen as well as arginine deaminase activity during all three crop periods. In 1997, a 22.73% decrease in plant available nitrogen ($p \leq 0.05$) (**Figure 1**) and a 7.23% decrease ($p \leq 0.05$) in enzyme activity (**Figure 4**) were observed in treated fields after 15 days of treatment. The decrease in arginine deaminase activity continued till 90 days after sowing. In 60th and 90th day samples, 11.98 and 6.18% declines in enzyme activity ($p \leq 0.05$) were observed in treated fields (**Figure 4**). During the whole experimental period, lindane residues varied from 10.80 ± 1.4 to 51.12 ± 2.1 ηg/g dry wt soil (**Table 5**). In 1998, 6.61 and 8.20% decreases ($p \leq 0.05$) in available nitrogen were observed in 30th and 60th day samples (**Figure 2**). However, 14.50, 7.96, and 17.81% decreases in enzyme activity ($p \leq 0.05$) were observed in 30th, 60th, and 90th day samples, respectively (**Figure 5**). Lindane residues in 30−90 day samples varied from 38.33 ± 4.7 to 16.00 ± 2.9 ηg/g dry wt soil (**Table 5**).

In 1999, almost similar results were observed as in 1997 and 1998. Plant available nitrogen was 11.25% less in treated fields as compared to the control field after 30 days of treatment. This trend was continued till 60 days (**Figure 3**). However, an adverse effect of lindane seed treatment on arginine deaminase activity was observed in 15th and 60th day samples, which indicated 16.41 and 13.66% reductions in enzyme activity (**Figure 6**). Lindane residues varied from 34.11 ± 3.7 to 48.53 ± 5.1 ηg/g dry wt soil during 15−60 days after sowing (**Table 5**).

Lindane seed treatment had adverse effects on plant available nitrogen during all three experimental years. Likewise, initially suppressed an then subsequently increased ammonification was observed (*25*) in clay soil supplemented with 2% compost lindane. Lindane in loam soil suppressed the microbial population in dry soils but stimulated ammonification in moist soils (*26*).

It was also observed that lindane seed treatment had adverse effects on arginine deaminase activity for all of the three experimental years, which was found between 15 and 60 or 30 and 90 days. Hussain et al. (*27*) observed a significant decrease in arginine ammonification in the 0−15 cm soil profile after pesticide treatments in clay loam fields. A significant decrease in NH_4^+-N content of the soil was also found after carbofuran application in cultivated soil (*28*). The average half-life of lindane was found to be 53.39 days. However, some authers have repoted that the lindane is highly persistent in most of the soils with a half-life of approximately 15 months (*29*). However, a short half-life of lindane was also found when it was sprayed on the surface rather than incorporated into the soil (*30*).

In our experiments, we have observed the stimularory effect of daizinon and imidacloprid on arginine deaminase activities. Imdachloprid also has a stimulatory effect on plant available nitrogen. The effect was temporary, and it usually recovered to normal in comparison with the control within a few days or weeks. The adverse effects of lindane residues on plant available nitrogen and arginine deaminase activities may be due to the toxicity of insecticides on soil microbes and biochemical activities leading to mineralization. However, a gradual increase in the available nitrogen and arginine deaminase activities may be due to the adaptability of microbes toward the toxic compounds. Schuster and Schroder (*18*) found the inductive adaptation of the soil fungi when insecticides were applied repeatedly in consecutive years. Many authors have reported that the insecticides had a temporary effect on the microbial population at recommended doses and it recovered in favorable conditions (*31*).

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