
Monitoring the Persistence of Devrinol, Diazinon, and Trifluralin Residues in Soil Following Application of Organic Amendments

George Fouad Antonious

Division of Environmental Studies, College of Agriculture, Community and the Sciences, Kentucky State University, Frankfort, USA

Email address:

george.antonious@kysu.edu

To cite this article:

George Fouad Antonious. Monitoring the Persistence of Devrinol, Diazinon, and Trifluralin Residues in Soil Following Application of Organic Amendments. *International Journal of Applied Agricultural Sciences*. Vol. 8, No. 3, 2022, pp. 104-112.

doi: 10.11648/j.ijaas.20220803.11

Received: February 23, 2022; **Accepted:** March 18, 2022; **Published:** May 10, 2022

Abstract: Pesticides have the potential mobility from the site of application to natural water resources leading to surface water quality problems. Binding pesticides to soil lead to immobilization preventing their mobility into surface water and enhancing their availability for degradation by soil microorganisms and their secreting enzymes. The impact of low-cost organic amendments used in agricultural operations on the persistence of three pesticides; devrinol, diazinon, and trifluralin in agricultural soil was investigated. Pesticide residues in sewage sludge (SS), farm compost (Comp), and no-mulch (NM) control treatment following field application were monitored at different time intervals using solvent partitioning and gas chromatographic procedure (GC). Half-life ($T_{1/2}$) values of the three pesticides in soil were determined under three farming practices to investigate how long each pesticide remains in each soil treatment. Results revealed the retention of devrinol by 30%, diazinon by 55%, and trifluralin by 80% in soil amended with SS compared to sole NM soil used as control treatment. This practice might prevent the off-site movement of pesticides. Devrinol $T_{1/2}$ value of 14.1 days was significantly ($P \leq 0.05$) lower in soil amended with Comp compared to SS amended soil due to its high dissipation constant (K). Diazinon residues fluctuated during the first week after spraying and started to decline, reaching a minimum value of $0.004 \mu\text{g g}^{-1}$ soil at 35 days after spraying. Its $T_{1/2}$ value of 10.6 days was significantly lower in SS amended soil compared to Comp waste and control treatments (15.8 and 18.5 days, respectively). Trifluralin residues in NM soil showed a low dissipation constant and greater ($T_{1/2}$) value of 116 days. Its dissipation and degradation in soil amended with Comp and SS indicated half-life ($T_{1/2}$) values of 48.5 and 34.6 days, respectively. The low adsorptive capacity of devrinol due to its high-water solubility requires minimizing its application rates in agricultural regions to prevent environmental contamination of natural water resources.

Keywords: Pesticide Binding, Gas Chromatography, Dissipation Constants, Half-Lives, Initial Residues

1. Introduction

The demand for food is growing and a large amount of plant production practices will depend on the application of pesticides and organic fertilizers. Synthetic pesticides protect plants from insects, diseases, and pathogens attack that decrease agricultural productivity. Pesticides application in agriculture while being of a great assistance in limiting pests, can cause a danger to environmental quality. Their application periods are usually coincided with seasonal rainfall. In crop production areas, pesticides use in agriculture contaminate surface runoff. According to published data, the U.S. used >

441 million kg of traditional pesticides in the agriculture sector [1], of this amount 77% used in agricultural applications causing 1,200 water body damages across the U.S. [2]. Conversely, the U.S. produces millions dry tons of urban sewage sludge (SS) each year and this amount is rising due to human population growth. Yard waste compost, such as leaves, vegetable remains and plant parts, straw, and grass clippings are available in large amounts in most farms. The use of SS as organic fertilizer could be a beneficial practice for catching pesticides, such as dimethazone [3], metribuzin [4] and napropamide [5]. Soil amendments including farm waste and farm vegetable remains and their organic matter content have

important effects on the availability, persistence, biodegradability, leaching, and volatility of chemicals in the environment. Soil amendments capture pesticide in contaminated runoff from agricultural operations and offer a potential solution to pesticide contamination of natural water resources arising from farmlands. Investigators [6-12] reported a positive relationship between soil organic matter and crop biomass, nutritional composition, and crop productivity. The addition of organic amendment to agricultural soil increased soil microbiological activity [13-16] due to their content of simple natural molecules, such as sugar and amino acids. The use of organic amendments provides organic matter and essential nutrients beneficial for improving soil composition and nutrient level [14], and commonly stimulates soil bacterial population [9, 11, 17, 18].

Diazinon (O, O-diethyl-O-(2-isopropyl-4-methyl-6-pyrimidinyl) is commonly used as a thiono-phosphorous organophosphate insecticide to control variety of insects in agriculture as a nerve poison. Thiophosphate pesticides can transform to metabolites, such as oxygen analogues that are several hundred times more effective acetylcholine inhibitors compared to their original compound [19]. Devrinol (napropamide) is a pre-emergent herbicide and treflan (trifluralin), also is a pre-emergent herbicide used to control of annual grasses and broadleaf weeds [20]. The objectives of this investigation were to: 1) determine the organic matter, elemental composition, and C/N ratio of sewage sludge (SS), farm waste compost (Comp), and control soil. 2) determine the dissipation constants and half-life ($T_{1/2}$) values of devrinol, diazinon, and trifluralin residues in soil amended with SS and Comp following their application under field conditions.

2. Materials and Methods

2.1. Field Experiment

The field study, designed on a Lowell silty-loam soil (2.2% organic matter, pH 6.9) was located at Kentucky State University (KSU) Harold R. Benson Research and Demonstration Farm (Franklin County, KY, USA). The soil has an average of 12% clay, 75% silt, and 13% sand. Eighteen (18) field plots (22 m × 3.7 m each) were used to investigate the persistence of devrinol, treflan, and diazinon in soil following the addition of soil amendments. The 18 plots (3 soil treatments × 6 replicates) were separated using metal borders 20 cm above ground level to prevent cross contamination between adjacent treatments. The three soil treatments were: 1) municipal sewage sludge (MSS class A bio solids) obtained from Nicholasville Wastewater Treatment Plant (Versailles, KY, USA), treated with lime (Ca O) at 1:10 (w/w) ratio, and mixed with native soil at 15 t acre⁻¹ (on dry weight basis). 2) farm waste compost made from yard and lawn trimmings and vegetable remains obtained from KSU Research Farm and used at 15 t acre⁻¹ (on dry weight basis). 3) no-mulch (NM) native soil used as control treatment. Prior to planting, soil amendments were mixed with native soil to a plowing depth of 15 cm and sprayed with Devrinol

(napropamide) and Treflan (trifluralin) herbicides at the recommended rates of application [20] according to Kentucky agricultural guidelines. Devrinol 50-DF, also known as napropamide [N, N -diethyl-2-(1-naphthoxy) propionamide] was obtained from United Phosphorus, Inc. (Exton, PA) and applied at the rate of 4 lbs. of formulated product acre⁻¹. Treflan [trifluoro-2, 6-dinitro-N,N-dipropyl-p-toluidine] was obtained from Aceto Corporation (New York, USA) and applied at 430 g liter⁻¹ EC to control annual and broadleaf weeds. Potato (*Solanum tuberosum* variety Kennebec) tubers were cut to small pieces and planted at 10 pieces row⁻¹. Diazinon AG 500 [O, O-diethyl O-[4-methyl-6-(propan-2-yl) pyrimidin-2-yl] phosphorothioate], a nonsystemic organophosphorus insecticide was obtained from ADMA Global (Raleigh, NC, USA) and sprayed on the potato foliage at 0.75 pints acre⁻¹ one month after planting to control soil and potato foliage insects. Herbicides were sprayed using a 4-gallon portable backpack sprayer (Solo) equipped with one conical nozzle operated at 40 PSI and incorporated into the soil to a depth of 15 cm for control of annual and perennial grasses [21]. Diazinon was sprayed on potato foliage at a height of 15-20 cm above plant canopy in a total volume of 157.5 L of water acre⁻¹ to control potato insects.

2.2. Soil Samples

Representative soil samples (taken from 3 cores per plot) were collected from the different field treatments using a soil core sampler equipped with a plastic liner tube (Clements Associates, Newton, IA) of 2.5 cm i.d. for maintenance of sample integrity. Soil samples were taken to a depth of 15 cm from the rhizosphere of growing potato plants within the treatments prior to and after pesticides application during the course of the study (1 hour – 35 days). Soil samples (6 replicates per treatment) were air dried in the dark at room temperature for 48 h and sieved to size of 2mm for pesticide residue analyses.

2.3. Pesticide Residue Analysis

One hundred g representative soil samples, taken at different time intervals during the growing season (1 hour – 35 days) were shaken with a mixture of methylene chloride: acetone (1:1 v/v) for 1 h using a multi-purpose shaker (Lab-Line Instruments Inc., Melrose Park, IL, USA) to extract devrinol (napropamide), diazinon, and Treflan (trifluralin) residues. Each mixture was filtered through Whatman 934-AH glass microfiber discs (Fisher Sci., Pittsburg, PA) of 90 mm diameter. The soil extracts were passed through anhydrous Na₂SO₄ to remove any traces of water, concentrated by rotary vacuum (Buchi Rotavapor Model 461, Switzerland), and N₂ stream evaporation. Each of the concentrated extracts passed through a 0.45 µm GD/X disposable syringe filter (Fisher Scientific, Pittsburg, PA). One µL (n=3) of each soil extracts was injected into a gas chromatograph (GC) equipped with a nitrogen-phosphorus detector (GC/NPD). The gas chromatograph (HP 5890, Hewlett Packard, Palo Alto, CA) was equipped with a 30-m (0.23-mm diameter, 0.33-µm film thickness) fused silica

capillary column (HP-5) of 5% phenyl polysiloxane and 95% methyl polysiloxane liquid phase. Temperatures of operation were 230, 250, and 280°C for injector, oven, and detector, respectively. Area units were obtained from one- μ L injections. Linearity over the range of concentrations was determined using regression lines ($R^2 > 0.95$) and peak areas were calculated using HP 3396 series-II integrator. Quantification was based on average peak areas from three consecutive injections obtained from external standards of devrinol, diazinon, and trifluralin >97% purity. Peak identity was confirmed by consistent retention time and coelution with standards under the conditions described earlier. Under these conditions, retention times (Rt) values averaged 6.88, 8.18, and 10.99 min. for trifluralin, diazinon, and devrinol, respectively.

Standard solutions of each pesticide in acetone ranging from 0.1 to 15 ng L⁻¹ were prepared and used to spike blank soil for evaluating the reproducibility and efficiency of the analytical procedures used. After fortification at 30 - 45- μ g g⁻¹ soil, pesticides were extracted and the residues of each compound were determined using the same procedure as described above. Recovery (means \pm SD) of devrinol, diazinon, and trifluralin from fortified soil samples were 93 \pm 1.8, 88 \pm 0.96, and 95 \pm 2.4%, respectively. Pesticide residues detected in soil were used to calculate half-lives ($T_{1/2}$) values in each soil treatment. Half-lives were calculated from regression lines using the equation $T_{1/2} = \ln 2/K$, where $K = -2.302 \times$ slope of the line. Three sets of duplicate samples and three sample spikes were used to evaluate potential bias of the data collected and the ability of the analytical procedure to recover analytes from soil samples.

Residues of the three pesticides were related to soil management technique, and statistically analyzed using ANOVA procedure and Duncan's multiple range test for mean comparisons [22].

3. Results and Discussion

Napropamide (Devrinol, Figure 1) has a considerable polarity (water solubility of 74 mg L⁻¹ at 25°C [23]). Its dissipation and degradation in soil involves both biotic and abiotic pathways that begins with breakdown of the two alkyl groups at the N atom and followed by transformation of the amide to carboxylic acid [24]. Following spraying, the initial deposit (one hour after spraying) of 0.302 μ g g⁻¹ in native soil dropped to 0.267 and 0.02 μ g g⁻¹, respectively after 7 and 30 days under filed conditions indicating a dissipation constant of 0.04 and half-life ($T_{1/2}$) value of 17.2 days (Table 1). These results are in agreements with Biswas et al. [23] who reported that dissipation and breakdown of devrinol in soil follow a first-order kinetics resulting half-lives in the range of 12.54–27.87 days. Results also revealed that following the addition of SS to native soil, devrinol dissipation constants significantly reduced from 0.04 to 0.026 indicating a longer persistence and $T_{1/2}$ value of 26.6 days (Figure 1 and Table 1) compared to $T_{1/2}$ value of 17.2 days in native soil not amended with SS compost. Devrinol $T_{1/2}$ value of 14.1 days was significantly ($P \leq 0.05$) lower in soil amended with farm waste compost compared to SS amended soil due to its high dissipation constant (K) as shown in Table 1. This low $T_{1/2}$ value is an indicative of its mobility and potential impact on aquatic systems.

Table 1. Dissipation pattern of three pesticides in soil under three management practices.

Pesticide	Log K _{ow}	Soil Treatments	Initial Deposits, μ g g ⁻¹	Slope of the line (b)	Dissipation Constant (K)	Half-Lives ($T_{1/2}$) in days
Devrinol	3.4	Sewage Sludge	0.1280	-0.0113	0.026024	26.63 a
		Yard Compost	0.2330	-0.0214	0.049284	14.06 b
		No-Mulch	0.3017	-0.0175	0.040303	17.19 b
Diazinon	3.3	Sewage Sludge	0.0586	-0.0283	0.065175	10.63 c
		Yard Compost	0.0260	-0.0191	0.043987	15.75 b
		No-Mulch	0.0222	-0.0163	0.037539	18.45 a
Trifluralin	4.83	Sewage Sludge	0.2255	-0.0087	0.020036	34.59 c
		Yard Waste	0.2510	-0.0062	0.014279	48.53 b
		No-Mulch	0.1544	-0.0026	0.05988	115.73 a

Dissipation constant (K) = $-2.303 \times$ slope of the dissipation line; $T_{1/2} = \ln 2/K$. Comparisons were performed among soil treatments for each pesticide. $T_{1/2}$ values having different letters revealed significant ($P \leq 0.05$) differences (SAS Institute, 2016) [22].

Table 2. Properties of soil of the rhizosphere of potato plants grown at KSU Harold Benson Research and Demonstration Farm, (Kentucky, USA).

Composition	Sewage sludge incorporated with native soil	Yard waste incorporated with native soil	Native soil
% N	0.39 a	0.32 a	0.15 b
% P	0.31 a	0.24 a	0.18 b
% K	0.19 a	0.28 a	0.15 b
% C	3.7 a	3.8 a	1.6 b
% Organic matter	5.9 b	7.6 a	2.2 c
C/N ratio	9.2 c	11.9 b	17.7 a
pH	8.5 a	7.3 b	6.9 b

Determination of pH value was carried out using a soil: distilled water slurry of 1:5 (w/v). Organic matter was estimated dry subtraction of ash content from dry soil weight. Percent Nitrogen was calculated using the Kjeldahl method. Composition of soil elements was determined using an Inductively Coupled Plasma (ICP) Spectrometer after sample digestion with HCL and H₂SO₄. Comparisons among soil treatments were done for each soil parameter. Values in each row accompanied by the same letter indicate no significantly differences ($P > 0.05$) utilizing Duncan's multiple range test (SAS Institute, 2016) [22].

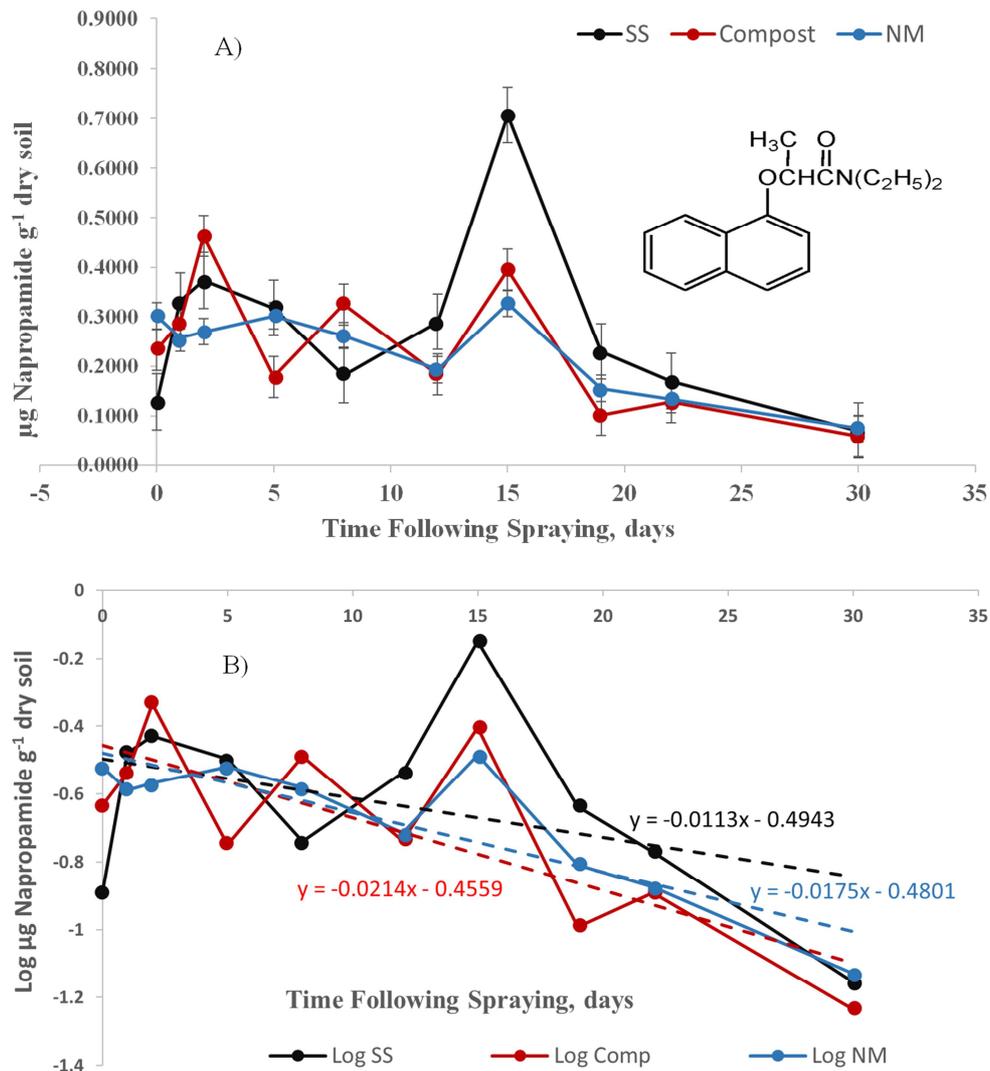


Figure 1. Dissipation of napropamide (devrinol) expressed as $\mu\text{g g}^{-1}$ soil amended with sewage sludge (SS) or farm waste compost (Compost) compared to native soil (NM) used as control treatment following spraying with Devrinol 50-DF (A) and $\text{log } \mu\text{g g}^{-1}$ soil (B). Values represent average of six replicates \pm standard deviation.

Diazinon residues fluctuated during the first week after spraying and started to decline reaching a minimum value of $0.004 \mu\text{g g}^{-1}$ soil 35 days after spraying (Figure 2A). As described earlier, diazinon was sprayed on potato foliage and its residues in soil are mainly due to both drift during spraying and wash-off residues following natural rainfall events. Diazinon dissipation pattern in soil amended with farm waste compost and SS compost presented in Figure 2 indicated a greater dissipation constant (K) in soil amended with SS compared to soil amended with farm compost and native soil (control treatment). Accordingly, the ($T_{1/2}$) value of 10.6 days was significantly ($P \leq 0.05$) lower in SS amended soil compared to farm waste compost and control treatments (15.8 and 18.5 days, respectively) (Table 2). One also should consider that the increase in soil temperature and availability of water in soil usually enhance pesticides' degradation and volatility. In addition, water as a polar molecule may compete with pesticides for adsorption sites on soil particles and organic matter in SS lessening their adsorption and binding to soil organic matter.

Trifluralin (Treflan) is a nonpolar herbicide that has a low water solubility of 0.22 mg L^{-1} at 25°C [25]. Following trifluralin spraying, the initial deposit of $0.15 \mu\text{g g}^{-1}$ in native soil revealed a low dissipation constant and greater $T_{1/2}$ value of 116 days. Its potential dissipation and degradation in native soil ($K = 0.06$) that involve breakdown by soil organisms, sunlight, plant roots, and soil solution [26] was reduced in soil amended with farm waste and SS compost indicating half-life ($T_{1/2}$) values of 48.5 and 34.6 days, respectively. This decrease in $T_{1/2}$ values after the addition of soil amendments might be due to trifluralin adsorption as nonionic, non-polar hydrophobic compound. According to Sparks [27], humic substances present in soil organic matter contain aromatic framework and hydrophobic sites. The hydrophobic sites might combine with nonpolar compounds on soil organic matter, which include fats, waxes, resins, and aliphatic side chains. Bonding of nonpolar pesticides to soil organic matter is likely a pesticide-lipid interaction [28]. Lipids in soil are coupled with soil humus (a sticky brown insoluble organic matter), accordingly pesticide adsorption

by soils would depend on the soil organic matter content. The increased organic matter in soil due to compost addition plays an important role in the adsorption of non-polar pesticides, such as trifluralin. This management practice could be used for bonding (trapping) non-polar pesticides to

reduce surface water and groundwater contamination by nonpolar pesticide residues. In addition, humic substances, with numerous oxygen- and hydroxyl functional groups form hydrogen bonds with pesticide molecules that compete with water for these binding sites.

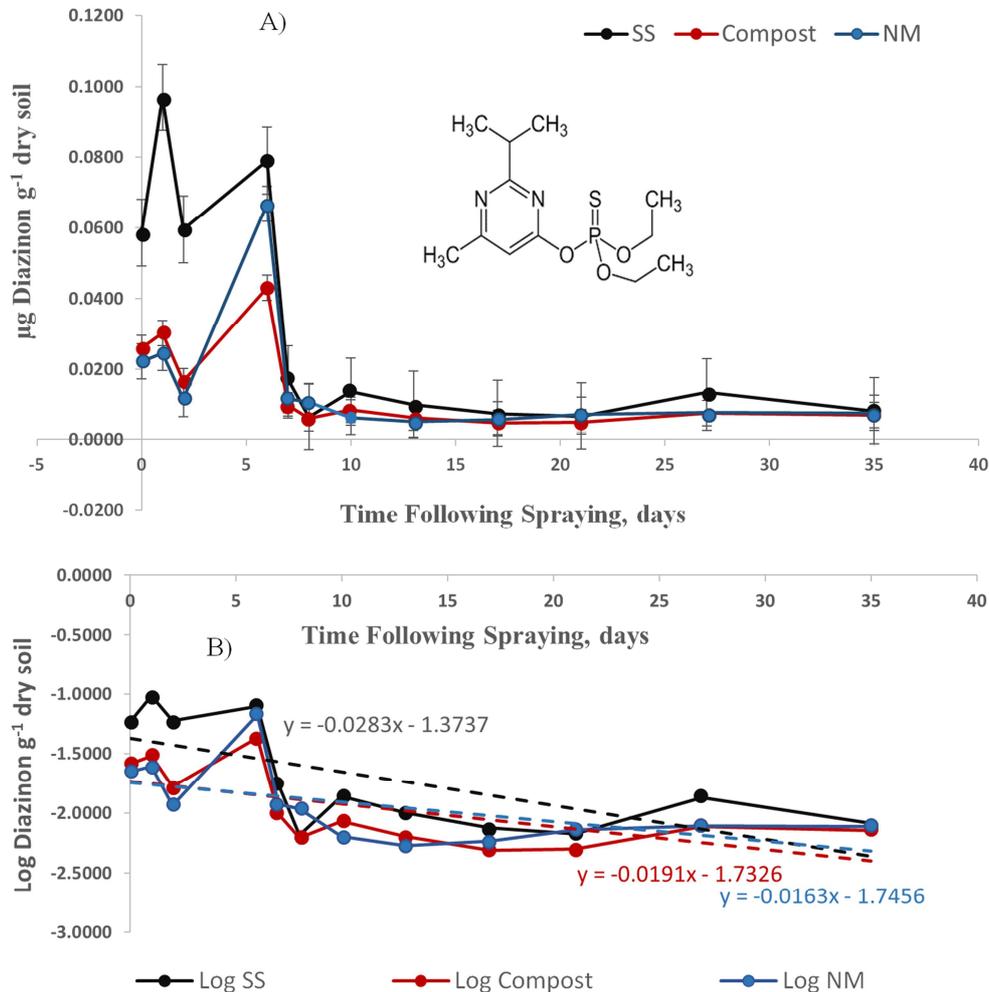


Figure 2. Dissipation of diazinon expressed as $\mu\text{g g}^{-1}$ soil amended with sewage sludge (SS) or farm waste compost (Comp) compared to native soil (NM) following spraying with diazinon AG500 on plant foliage (A) and $\text{log } \mu\text{g g}^{-1}$ soil (B). Values represent average of six replicates \pm standard deviation.

Hydrogen bonds perform an important part in the adsorption of several non-ionic and polar pesticides, substituted urea, and phenyl-carbamate pesticides [29; 30]. According to several investigators [31; 32], the adsorption energy involves impacts from both electrostatic and chemical interactions and therefore the pesticide molecule is not likely to leach or runoff when bounded to soil particles. On the contrary, adsorption of negatively charged anions on the negatively charged clay and organic surfaces in soil is very low due to repulsion. The greater clay particles and organic matter in soil, the greater pesticide adsorption and bonding. Pesticides adsorbed to soil do not leach or move from the site of application unless the soil particles to which they are adsorbed move through erosion with water following irrigation and rainfall events. The longer the pesticide molecules are held, the more likely is microbiological degradation will occur, which reduces the risk of leaching

through the soil column into groundwater or reaching natural water resources through runoff.

The increase in trifluralin residues in the three soil treatments (Figure 3) during the first eight days after spraying followed by its disappearance rate gradually with time during the 10-35 days might be explained in part to trifluralin adsorption and decomposition. Some investigators reported that the behavior of trifluralin in soil appears to differ in some cases from the general adsorption rules surveyed by most neutral herbicides [33]. Trifluralin often strongly adsorbed on soil organic matter due to its low water solubility (0.22 mgL^{-1}) that permits a very restricted movement in soil. Trifluralin decomposition in soil can be through microbiological and non-biological processes [34]. On the other hand, it was reported that trifluralin phytotoxicity increased in soil amended with organic matter content [35]. Some studies have also indicated that in-spite-of

its low water solubility, trifluralin may contaminate groundwater and surface water. In fact, this herbicide has been detected in surface water in studies reported by the U.S. Geological Survey [36]. This behavior might be due to the

ionic structure of trifluralin (Figure 3), the low or negative absorption of the herbicide could be due to the repulsion from the negatively charged clay and organic matter surfaces in organic amendments, such as SS and farm waste compost.

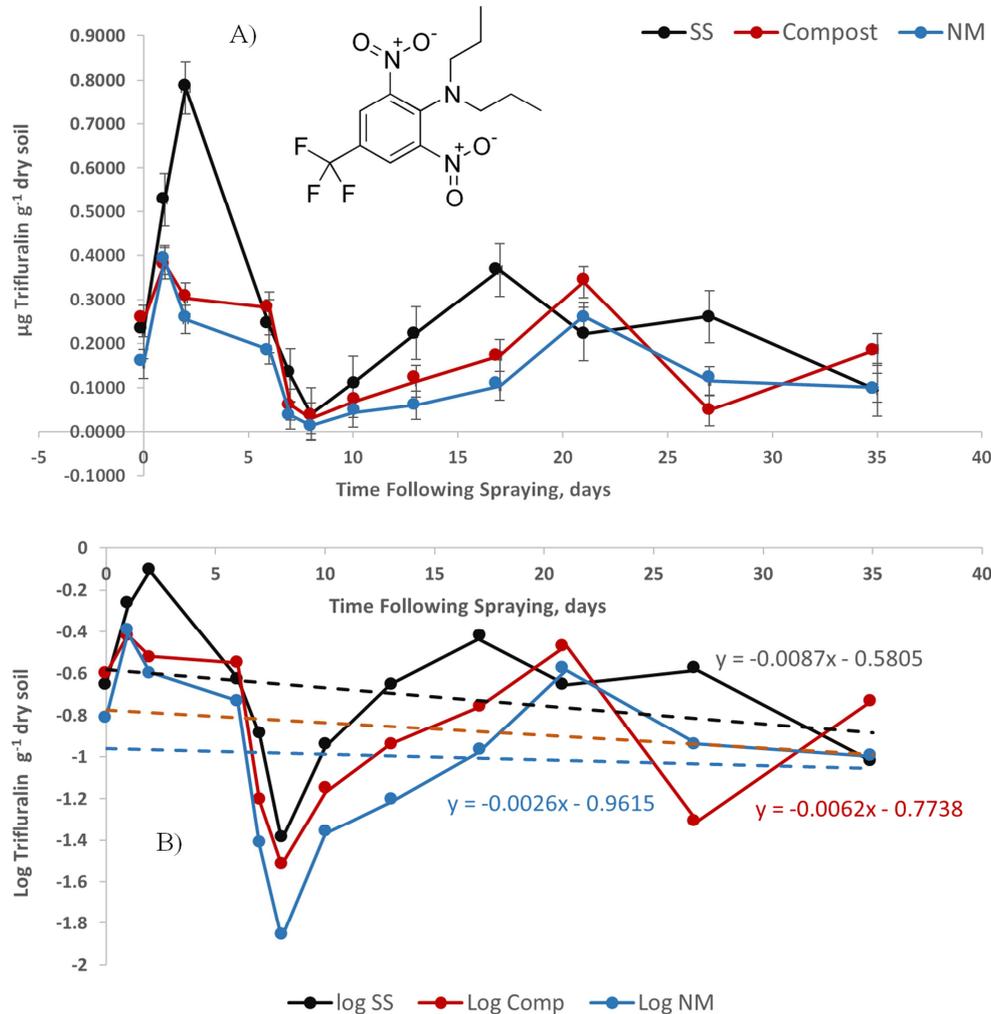


Figure 3. Dissipation of trifluralin expressed as $\mu\text{g g}^{-1}$ soil amended with sewage sludge (SS) or farm waste compost (Compost) compared to native soil (NM) used for comparison purposes following spraying with Treflan EC (A) and $\log \mu\text{g g}^{-1}$ soil (B). Values represent average of six replicates \pm standard deviation.

Pesticides with high log Kow values have a tendency to be adsorbed to soil organic matter and sediment particles due to their low affinity for water molecules. Pesticides with very high log Kow values (> 4.5), such as trifluralin (Table 1) are often bonded to hydrophobic substances, such as soil particles reducing their mobility into surface and ground water, however they are of greater fear since they also have the potential to bio-accumulate in living organisms.

Composition of soil amendments used in this investigation was analyzed and presented in Table 2 that might explain the variability among three soil treatments. Table 2 indicated that the addition of organic amendments to agricultural soil reduced the C/N ratio. Kizilkaya and Bayrakli [37] reported that the addition of N in form of ammonium sulfate $[(\text{NH}_4)_2\text{SO}_4]$ to soil reduced the C/N ratio from 9:1 to 3:1 and this decrease resulted in a quick increase in soil enzymatic activities. In addition, other investigators [38; 39] reported

that reducing the C/N ratio is symptomatic of a high organic matter decomposition rate. However, others [40] found that organic matter with high level of C/N ratios had relatively low rates of decomposition and caused low rates of N-mineralization in soil. Table 2 also revealed that the concentrations of NPK, C, and organic matter were greater in SS and farm waste compost. Soil pH was increased significantly by 23% due to SS compost addition to native soil.

Figure 4A represents the overall persistence of the pesticides investigated in the current study under each of the three soil treatments, regardless of pesticide type. This indicates the greater persistence in soil amended with SS compared to farm waste amended soil. Figure 4B revealed that in spite of the variability of water solubility among the three pesticides, each of the three pesticides persisted longer in SS amended soil compared to soil amended with farm

waste compost. The overall average of devrinol residues in SS amended soil ($0.29 \mu\text{g g}^{-1}$ dry soil) was significantly ($P \leq 0.05$) greater compared to farm compost and native soil (0.24 and $0.22 \mu\text{g g}^{-1}$ dry soil, respectively), indicating a greater retention of 32% due to addition of SS compost to native soil. Diazinon residues in SS amended soil ($0.031 \mu\text{g g}^{-1}$ dry soil) also were significantly ($P \leq 0.05$) greater compared to farm compost ($0.015 \mu\text{g g}^{-1}$ dry soil), indicating a greater retention of 55% due to addition of SS to native soil. Trifluralin residues persisted longer (about 80% retention) in SS amended soil compared to the control treatment (native soil). It could be concluded that the adsorption of pesticides to soil depends on several factors other than soil organic matter and water solubility. A given pesticide may undertake binding by several binding processes all together. The increased persistence of a pesticide in soil decrease bioavailability due to formation of tougher bonds that increase residence times

in soil or could be due to physical entrapment of the compound in the soil organic matter or mineral matrix. This may involve the formation of covalent bonds or sorption onto soil particles or diffusion into soil and entrapment within soil organic matter. Adsorption also depends on the physicochemical properties of the pesticide that impact its behavior and biological activity in soil. Pesticide molecular size, ionizability, water solubility, lipophilicity, configuration, soil pH, and pesticide volatility are all asset or retard binding. Future plants will include the use of batch equilibrium/adsorption isotherm experiments to investigate pesticides adsorption to soil mixed with animal manures (chicken manure, horse manure, sewage sludge, vermicompost, and cow manure) as well as biochar amended with animal manures to investigate the impact of the various soil amendments on the adsorption and mobility of pesticides.

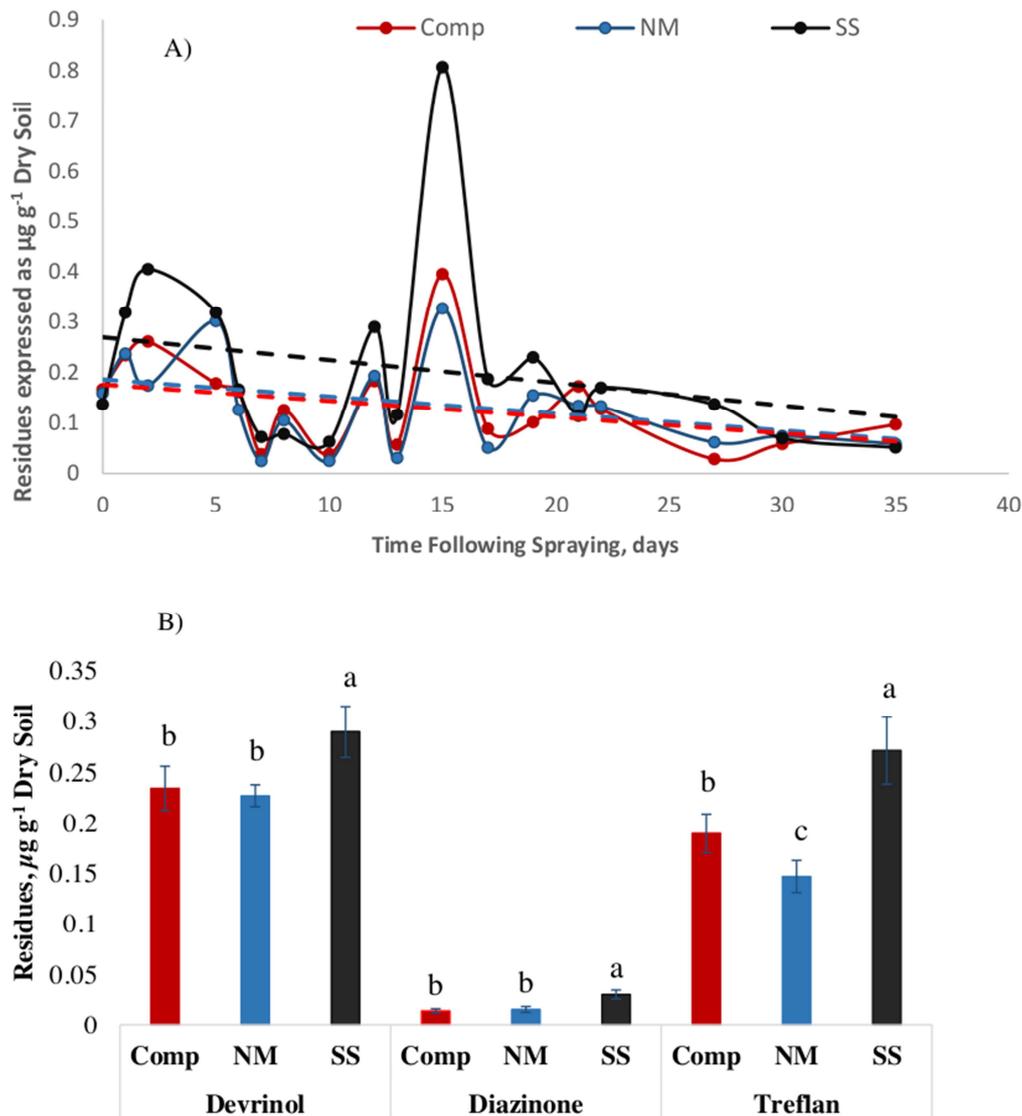


Figure 4. Dissipation of pesticide residues in soil amended with farm waste compost, no-mulch native soil, and municipal sewage sludge following spraying at different time intervals (A) and overall average of each pesticide under three soil management practices (B). Statistical comparisons were carried out among the three soil treatments for each pesticide. Bars having different letters indicate significant differences ($P \leq 0.05$). Values represent average of six replicates \pm standard deviation.

4. Conclusion

Two herbicides (devrinol and trifluralin) and one insecticide (diazinon) were sprayed under field conditions in a randomized complete block design to determine their dissipation rates and half-life ($T_{1/2}$) values in soil following application of soil amendments (farm waste and sewage sludge compost). A gas chromatograph (GC) equipped with a nitrogen phosphorus detector (NPD) was used for quantification of pesticides residues in soil during potato growing season. Residues of devrinol that has considerable polarity dropped from $0.302 \mu\text{g g}^{-1}$ in native soil to 0.267 and $0.02 \mu\text{g g}^{-1}$, respectively after 7 and 30 days indicating a dissipation constant of 0.04 and half-life ($T_{1/2}$) value of 17.2 days. Results also revealed that following the addition of SS to native soil, devrinol dissipation constants significantly reduced from 0.04 to 0.026 indicating a longer persistence and $T_{1/2}$ value of 26.6 days compared to $T_{1/2}$ value of 17.2 days in native soil not amended with SS compost. Devrinol $T_{1/2}$ value of 14.1 days was significantly ($P \leq 0.05$) lower in soil amended with farm waste compost compared to SS amended soil due to its high dissipation constant (K). This low $T_{1/2}$ value is an indicative of its mobility and potential impact on aquatic systems. Diazinon residues fluctuated during the first week after spraying and started to decline reaching a minimum value of $0.004 \mu\text{g g}^{-1}$ soil 35 days after spraying. Diazinon dissipation pattern in soil amended with farm waste and SS compost indicated a greater dissipation constant (K) in soil amended with SS compared to soil amended with farm waste compost and native soil (control treatment). Its $T_{1/2}$ value of 10.6 days was significantly ($P \leq 0.05$) lower in SS amended soil compared to farm waste and control treatments (15.8 and 18.5 days, respectively). Trifluralin (Treflan) is a nonpolar herbicide that has a low water solubility of 0.22 mg L^{-1} , following trifluralin spraying, the initial deposit of $0.15 \mu\text{g g}^{-1}$ in native soil revealed a low dissipation constant and greater ($T_{1/2}$) value of 116 days. Its potential dissipation and degradation in native soil was reduced in soil amended with yard waste and SS indicating half-life ($T_{1/2}$) values of 48.5 and 34.6 days, respectively. The addition of soil amendments having high organic matter content, such as SS can be exploited as a management practice to trap nonionic pesticides and reduce their surface and subsurface mobility under field conditions. The low adsorptive capacity of devrinol due to their high-water solubility requires minimizing its field application rates in agricultural areas to prevent environmental contamination of natural water resources. Results also indicated that the addition of organic amendments to agricultural soil reduced the C/N ratio and increased the concentrations of NPK, C, and organic matter.

Future objectives will involve the use of animal manures (chicken manure, horse manure, cow manure, and vermicomposti) mixed with biochar and chitin to investigate their impact of pesticides persistence in soil.

Finance

This study was funded by the United States Department of Agriculture, National Institute of Food and Agriculture (USDA/NIFA) under award # KYX-10-18-65P Accession No. 1017900 to Kentucky State University.

Conflicts of Interest

The author declares that there is no conflict of interest.

Acknowledgements

The author like to thank Kentucky State University farm crew for their assistance in growing potato and spraying pesticides under field conditions.

References

- [1] U.S. Environmental Protection Agency (US EPA). Pesticide sales and usage report, 2004. EPA-733-R-04-001, Washington, D. C., USA.
- [2] U.S. Environmental Protection Agency (US EPA), Washington, D. C., 2004. National Summary of Impaired Waters and TMDL Information. Available at <http://iaspub.epa.gov/tmdlwaters10/attainnationcy.control?preporttype=T>
- [3] Antonious, G. F. (2000). Clomazone residues in soil and runoff: Measurement and mitigation. *Bull. Environ. Contam. Toxicol.* 64 (2), 168-175.
- [4] Antonious, G. F., Turley, T., Hill, R. (2014). Impact of soil amendments on metribuzin and DCPA half-lives and mobility into agricultural runoff water. *J. Environmental Science and Health, Part B* 49, 313–323.
- [5] Antonious, G. F., Patterson, M. A. (2005). Napropamide residues in runoff and infiltration water from pepper production. *J. Environ. Sci. Health*, B40 (3), 385-396.
- [6] Antonious, G. F. (2018). Impact of Animal Manure on Phytochemicals in Hot Pepper Fruits. Chapter 1, In: *Solanaceae: Cultivation, Nutrition and Health*. Edited by Rocka, IS, Plant Science Health and Practices, pages 1-42. Nova Science Publishers, New York, USA.
- [7] Antonious, G. F. (2016). Soil amendments for agricultural production. Chapter 7 In: *Organic Fertilizers: From Basic Concepts to Applied Outcomes*, Book chapter, July 2016, pages 157-187. Edited by Larramendy ML & Soloneski S, Published by Intech, Janeza Trdine 9, 51000 Rijeka, Croatia.
- [8] Antonious, G. F., Turley, E. T., Nkuwi, L. (2016). Impact of soil amendments and biochar on yield of tomato grown under field conditions. *Fruit and Vegetable Research Report, 2016 Annual Research Report*, University of Kentucky, College of Agriculture, Food and Environment, PR-721, pp. 25-26.
- [9] Antonious, G. F., Turley, E. T., and Dawood, M. (2020). Monitoring soil enzymes activity before and after animal manure application. *J. of Agriculture*, 10, 166.

- [10] Antonious, G. F., Turley, E. T., Shrestha D. S., and Dawood, M. H. (2021). Variability of biochar performance among soil amendments and enzymes activity. *International Journal of Applied Agricultural Sciences (IJAAS)*, 7 (1), 66-76.
- [11] Antonious, G. F., Dawood, M. H., Turley, E. T., and Paxton, R. B. (2021). Yield and quality of lettuce, pumpkin, and watermelon varieties grown under five soil management practices. *International Journal of Applied Agricultural Sciences (IJAAS)*, 7 (1), 57-65.
- [12] Antonious, G. F., Dawood, M. H., Turley, E. T., and Paxton, R. B. (2022). Biochar and animal manures increased yield of three varieties of turnips. *International Journal of Applied Agricultural Sciences (IJAAS)*, 8 (1), 50-56.
- [13] Antonious, G. F. (2009). Enzyme activities and heavy metals concentration in soil amended with sewage sludge. *J. Environ. Science & Health, Part-A Toxic/Hazardous Substances and Environmental Engineering*, A44, 1019-1024.
- [14] Antonious, G. F. (2003). Impact of soil management and two botanical insecticides on urease and invertase activity. *J. Environ. Sci. Health*, B38 (4), 479-488.
- [15] Cox L, Cecchi A, Celis R, Hermos'in M, Koskinen W, Cornejo J. (2001). Effect of exogenous carbon on movement of simazine and 2,4-D in soils, *Soil Sci. Soc. Am. J.* 65, 1688–1695.
- [16] Antonious, G. F., Turley, E. T., Snyder, J, C. (2008). Soil enzyme activity and heavy metal contamination in soil amended with sewage sludge. A paper presented at the International Symposium on Environment, Athens, Greece, May 22-25, 2008. Book chapter, In *Environmental Engineering & Economics*, by Michael Theophanides, Institute for Education and Research.
- [17] Barriuso, E., Houot, S., Serra-Wittling, C. (1997). Influence of compost addition to soil on the behavior of herbicides. *Pestic. Sci.* 49, 65-75.
- [18] Stratton ML, Rechcigl JE. Organic mulches, wood products, In: *Handbook of Soil Conditioners*. Wallace A.; Terry R. Eds. Marcel Dekker, Inc., New York, 1998, 43-95.
- [19] Colovic, M., Krstic, D., Petrovic, S., Leskovac, A., Joksic, A., Franko, M., Trebse, P., Vasic, V. (2010). Toxic effects of diazinon and its photodegradation products. *Toxicol. Lett.* 193, 9-18.
- [20] Coolong T, Bessin R, Jones T, Strang J, Seebold K. *Vegetable Production Guide for Commercial Growers*, Cooperative Extension Service Bulletin ID-36, University of Kentucky, College of Agriculture, 2011, Lexington, KY.
- [21] Aguer, J. P., Cox, L., Richard, C., Hermosin, M. C. and Cornejo, J. (2000). Sorption and photolysis studies in soil and sediment of the herbicide napropamide. *Journal of Environmental Science & Health Part B*, 35 (6), pp. 725-738.
- [22] SAS Institute Inc. *SAS/STAT Guide*, Version 6.4 SAS 2016 Inc., Campus Drive, Cary, NC 27513.
- [23] Biswas, P. K., Pramanik S. K., Mitra S. R., Bhattacharyya A. (2007). Persistence of napropamide in/ on tea under North-East Indian climatic condition. *Bull. Environ. Contam. Toxicol.* 79 (5), 566–569.
- [24] Donaldson S. G., Miller G. C. 1996. Coupled transport and photodegradation of napropamide in soils undergoing evaporation from a shallow water table. *Environ. Sci. Technol.* 30 (2), 924–930.
- [25] Tomlin, CDS. *The pesticide Manual*, 15th Edition published by the British Crop Production Council, 2009 British Library Cataloguing Publication Data (BCPC), Published by the Royal Society of Chemistry.
- [26] Messersmith C. G., Burnside, O. C. and Lavy T. L. (1971.) Biological and non-biological dissipation of trifluralin from soil. *Weed Sci.*, 19, 285-290.
- [27] Sparks, D. L. *Chemistry of soil organic matter*. In: *International Soil Chemistry*; Academic Press, San Diego, CA, 1995, 53-79.
- [28] Pierce, R. H. Olney, C. E., Felbeck, G. T. (1971). Pesticide adsorption in soils and sediments. *Environ. Lett.* 1 (2), 157-172.
- [29] Senesi, N., Testini, C., (1980). Adsorption of some nitrogenated herbicides by soil humic acids. *Soil Science* 10, 314-320.
- [30] Senesi, N., Testini, C. (1983). The environmental fate of herbicides: The role of humic substances. *Ecology Bulletin* 35, 477-490.
- [31] Dzombak, D. A., and F. M. M. Morel. (1990). *Surface complexation modeling: hydrous ferric oxide*. New York: Wiley and Sons.
- [32] Stumm, W. (1992). *Chemistry of the solid-water interface*. New York: Wiley and Sons. M. Colovic, D., Krstic, S., Petrovic, A., Leaskovac, G., Joksic, J., Savic, M., Franko, P., Trebse, V. Vasic. Toxic effects of diazinon and its photodegradation products. *Toxicol Lett*, 193, 9-18.
- [33] Horowitz, M., Nirahulin, T. Blumenfeld, T. (1974). Behaviour and persistence of trifluralin in soil., 14 (4), 213–220.
- [34] Messersmith, C. G., Burnside, O. C., Lavy, T. L. (1971). Biological and Non-Biological Dissipation of Trifluralin from Soil. *Weed Science Society of America*, 1971, pp. 285–90,
- [35] Bardsley, C. E., Savage K. E., Childers V. O. (1967) Trifluralin behavior in soil. I. Toxicity and persistence as related to organic matter, *Agron.* 59, 159-160.
- [36] Gilliom, R. J, Barbash, J. E., Kolpin, D. W., Larson, S. J. (1999). Testing water quality for pesticide pollution. *Environ. Sci. Technol.* 33, 164A-169A.
- [37] Kizilkaya, R., Bayrakli, B. (2005). Effect of N-enriched sewage sludge on soil enzyme activities. *Appl. Soil Ecol.* 30, 192–202.
- [38] Cotrufo, M. F., Ineson, P., Roberts, J. D. (1995). Decomposition of birch leaf litters with varying C-to-N ratios. *Soil Biol. Biochem.* 27, 1219–1221.
- [39] Recous, S., Robin, D., Darwis, D., Mary, B. (1995). Soil inorganic N availability: Effect on maize residue decomposition. *Soil Biol. Biochem.* 27, 1529–1538.
- [40] Vargas, D. N., Bertiller, M. B., Ares, J. O., Carrer, A. L., Sain, C. L. (2006). Soil C and N dynamics induced by leaf-litter decomposition of shrubs and perennial grasses in the Patagonian Monte. *Soil Biol. Biochem.* 38, 2401–2410.