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Dissipation dynamics of atrazine in soil under irrigated maize-cowpea cropping system

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Abstract
Atrazine, a triazine herbicide is an important herbicide used in India by maize growers. Researchers have used high doses of atrazine to control weeds in maize. However, little is known about the residue dynamics in the soil of these high doses under maize-cowpea cropping system. The persistence and degradation behaviour of extreme levels of atrazine in soil under irrigated maize-cowpea cropping system was assessed. Field experiments were carried out during consecutive years of 2019-20 and 2020-21 under sandy clay loam soil. Atrazine residues were determined by Agilent High Performance Liquid Chromatography (HPLC - 1200 series). Atrazine degradation pattern followed first order kinetics in the soil. The persistence of atrazine in the soil during *Kharif* seasons (2019 and 2020) was more in higher doses *viz*. 1.50, 1.75 and 2.00 kg a.i. ha^{-1} (110 days) whereas during *Rabi* seasons it was below detectable level (< 0.01 µg g^{-1}). Thus, atrazine has to be applied at the recommended rate (0.50 kg a.i. ha^{-1}) which has manifested shorter soil persistence (30 days) during the experimental period.

Keywords: HPLC, persistence, half-life, degradation, residue

Introduction
In agriculture, herbicides play a vital role in the control of weeds which keep up with the desired crop for all the resources such as water, nutrients, sunlight and space throughout the whole growth stages. According to Walker [1], agricultural soil is the terminal destination of a substantial number of herbicides, either when they are administered to the soil directly or on the shoots of plants. When these herbicides reach the ground, they interrelate with the environment and experience physical, chemical and biological degradation [2]. Globally, some of the herbicides have raised significant environmental concern due to their immoderate utilisation. This has led to diverse monitoring programmes to examine the environmental contamination and also for ecological risk evaluation. Herbicides have the ability to contaminate soil, ground and surface water. Atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) is a universal known herbicide. It is a photosynthesis inhibiting herbicide employed in agriculture as a selective pre – and – post emergence herbicide for control of grass and broad – leaved weeds in prime crops such as maize, sugarcane, sorghum, nuts and conifers [3]. Due to its immense utilisation and long half-life, atrazine has exorbitant environmental consequence [4]. It persists in soil for about 60 to 100 days and fairly dissolves in water [5]. Atrazine is comprehensively utilised as a desired herbicide for grassy and broadleaf weeds in India. According to Cheng *et al.* [6], it is the second most extensively consumed herbicide in the globe with about 70 000 – 90 000 tons annual consumption. Currently the recommended dose of atrazine for weed control in maize is 0.50 kg a.i ha^{-1}. Research works have been done by other researchers using high doses of atrazine to control weeds in maize. Foregoing studies conducted include the work of Moinuddin *et al.* [7] who reported that atrazine 50% WP at 2 kg a.i ha^{-1} may be safely utilized for effective weed control and better yield in maize. Notwithstanding, studies on the higher dose of atrazine sprayed in the maize-cowpea cropping system and their residue dynamics in the soil need to be studied. With this background, the present study was conducted with the aim to find out the persistence and degradation behaviour of these high doses of atrazine in soil under maize-cowpea cropping system.

Materials and Methods
Experimental site, layout and design
Field experiments were conducted during consecutive years of 2019-20 and 2020-21 at Eastern

Block Farm at Tamil Nadu Agricultural University, Coimbatore. The experimental farm was geographically situated in the Western agro-climatic zone of Tamil Nadu (11°N, 77°E) and at an altitude of 426.72 m above mean sea level. The field experiment was laid out as a randomized block design (RBD) with eleven treatments, replicated three times. The soil of the experimental field was sandy clay loam in texture and belongs to suborder chromoustert of the order *Vertisol*, classified taxonomically as *Typicustropep* (Soil Survey and land Use Organisation, 1998). The initial soil was high in available potassium (469.2 kg ha^{-1}), low in available nitrogen (246.4 kg ha^{-1}), available phosphorus (6.68 kg ha^{-1}), organic carbon (0.29%) and has the pH of 7.59 and EC (0.76 dSm^{-1}).

Treatment details, crop establishment, and management practices

The treatment details were; (T_1): pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}, (T_2): pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}, (T_3): pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}, (T_4): pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}, (T_5): pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}, (T_6): pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}, (T_7): pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}, (T_8): pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1} followed by tembotrione at 120g a.i ha^{-1} as post-emergence at 25 DAS, (T_9): pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1} followed by hand weeding at 30 DAS, (T_{10}): weed free check and (T_{11}): weedy check (control). The gross plot size was 4.8 m x 4.5 m. As per the treatments schedule, atrazine (50% WP) was applied as pre-emergence at 2 days after sowing of maize. The spray volume of 500 litres of water / ha was adopted

All the cultural practices and plant protection measures for crops, maize and cowpea other than the treatments were followed as per the recommendations of Crop Production Guide of Tamil Nadu Agricultural University (CPG, 2019). Maize seeds COH (M) 6 were sown manually on the side of the ridges with a spacing of 25 cm between plants and 60 cm between rows on 12th September during 2019 and on 8th July during 2020. Two seeds were placed per hill. The seed rate adopted was 20 kg ha^{-1} and the crop was raised under irrigated condition. The recommended dose of fertilizer *viz.*, 250: 75: 75 kg ha^{-1} nitrogen, phosphorus and potassium was adopted and applied in the form of Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O). A quarter (25%) of the dose of nitrogen, full dose of phosphorus and potassium were applied basally before sowing. Half dose (50%) of nitrogen was top dressed at 25 DAS and the remaining quarter at 45 DAS.

After harvesting of maize in each year, cowpea (var. Co (CP) 7) was raised in the same experimental field without disturbing the beds on 11th January 2020 and 6th November 2020 as a succeeding crop to find the residual effect of atrazine. Cowpea seeds were sown adopting a recommended spacing of 45 cm and 15 cm inter and intra row spacing respectively. The seed rate adopted was 25 kg ha^{-1}. The recommended dose of 25: 50: 25 kg NPK ha^{-1} was applied in the form of Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O). Full dose of fertilizer NPK was applied basally before sowing.

Chemicals, reagents and equipment

The analytical standard of atrazine was purchased from Sigma-Aldrich, Mumbai, India. The stock solution of atrazine was prepared by dissolving appropriate amount of atrazine in HPLC grade acetonitrile and stored in a freezer at -18 °C. Serial dilutions of varying concentrations were prepared by diluting with acetonitrile. HPLC and AR grade solvents were supplied by E-Merck. The water used was obtained by reverse osmosis system, followed by 0.25 µm filtration using the equipment from Millipore, equipped with an UV lamp, in order to obtain ultrapure water (resistivity of 18 MQ cm at 25 °C). The additional reagents employed in the present work were of analytical grade and supplied by SD Fine chemicals, Mumbai. An ultrasound bath (Soniclean, 47 Australia), under the constant frequency of 50/60 Hz pulses operating at 50/60 20 Hz pulses at a sweep bandwidth of 45 KHz and 170 W of power was employed. The device was equipped with a digital timer and a temperature controller (0 60 °C). An orbital shaker from Lab line, at 60 rpm for shaking extractions and Remi Cooling centrifuge of C-24BL model was used for extraction and centrifugation respectively.

Soil sampling

At the beginning of the experiment, just before land preparation, soil samples were collected from fifteen points in a zigzag pattern to ensure homogeneity. They were collected by driving screw auger to a plough depth of 15 cm, bulked together before a composite sample was taken. The soil was air dried and sieved through a 2 mm mesh sieve before subjected to chemical analysis (pH, electrical conductivity, organic carbon and available nitrogen, phosphorus and potassium).

For atrazine residue analysis, soil sampling was done on T_1 to T_7 only on each replication. Soil samples were collected at different time intervals *viz*. 0 (2 hrs.), 1, 3, 5, 7, 10, 15, 30, 45, 60, 75 and 90 days after herbicide application (DAHA) and lastly at harvest (110 days after treatment) under maize and 15, 30, 45, 60 DAS (days after sowing) as well as at harvest under cowpea. About 1 kg of soil sample from each plot was collected from five randomly selected spots at a depth of 15 cm using screw auger. The soil was mixed thoroughly and all unwanted materials were removed from the collected samples. Subsamples of about 250 g were sampled using the quartering technique and were kept in air tight plastic bags and transported to the laboratory for storage in a deep freezer (- 20 °C) for the analysis of atrazine residue.

Analytical techniques

Sample preparation

A valid homogenized representative soil samples weighing 50 g from each treatment in each replication were taken in 250 ml conical flask and atrazine was extracted using 100 ml solvent mixture consisting of methanol: distilled water (7:3 v/v) after shaking for 3 hours in orbital shaker. The soil suspension was centrifuged at 2500 rpm for 5 minutes and the supernatant was filtered through Whatman filter paper No. 41. Once more, 50 ml of the extract was added into centrifuge tubes and the same procedure as previously described was repeated. The supernatant phase was combined and partitioned with dichloromethane and evaporated to dryness using rotary vacuum flash evaporator. Lastly, the residue of atrazine was dissolved with 2 ml of acetonitrile HPLC grade solvent. The dissolved residue was filtered through 0.22 µm-pore-size Polytetrafluorethylene (PTFE) filters using a syringe filtration system and collected in vials before subjected to HPLC analysis.

Instrumental conditions

Atrazine residues were determined by Agilent HPLC (1200 series) equipped with Diode Array Detector (DAD), binary pump and auto sampler with rheodyne injection system. The separation of compounds were performed using Agilent Eclipse XDB-C 18, 5 µm, 4.6 x 150 mm column kept in thermo stated oven maintained at 30 °C. The instrument connected to a computer records the response in terms of peak area using the Ezchrome software. The detector response from 190 to 400 nm was stored to find out λ max of each compound. The optimized conditions used for determination of the compounds are given below:

1. Column: Agilent Eclipse C18, 4.6 x 150 mm, 5 µm
2. Mobile phase: Acetonitrile: MilliQ-Water (70:30% v/v)
3. Flow rate: 0.5 ml/min
4. Detector: Diode Array Detector
5. Wavelength (λ_{max}): 221 nm
6. Injection volume: 20 µl
7. Retention time: 3.28 ± 0.2 min
8. Limit of Detection (LOD): 0.01 mg/kg
9. Limit of Quantification (LOQ): 0.05 mg/kg

Calibration and residue calculation

A linearity check study was carried out with the help of analytical standard. Calibration curve was prepared by taking the areas corresponding to different concentrations of analytical standard. The concentrations taken were from 0.001 to 5.0 mg L^{-1} prepared in acetonitrile. The amount of herbicide molecules in the samples was calculated with the following formula:

$$\text{Residue in ppm } (\mu g\ g^{-1}) = \frac{A_1 \times C \times V_1}{A_2 \times W} \times R_f$$

Where

A1 = Area of compound from sample, in chromatogram
A2 = Area of compound from standard, in chromatogram
V1 = Total volume of sample in mL
C = Concentration of analytical standard in µg
W = Weight of the sample in g
Rf = Recovery factor

Method validation and recovery of atrazine: Before analysing the atrazine samples, recovery studies were carried out to establish the reliability of the analytical method employed for the present study. The blank soil sample parts were fortified with known concentrations of herbicide standard ranged from 0.001 to 2.0 mgL^{-1}. After 1 hour, fortified soil samples were subjected to an extraction and clean up to determine the recovery per cent of the herbicide compound. Quantification of atrazine residue concentration was accomplished by comparing the peak area response for samples with peak area of the standard.

The uncorrected µg g^{-1} of the fortified control samples was divided by the fortification level and multiplied by 100% to calculate the method recovery (%). The following equation was used:

$$\text{Method recovery (\%)} = \frac{\text{Uncorrected mg/kg} - \text{Control mg/kg}}{\text{Fortification level (mg/kg)}} \times 100$$

Precision standard deviation of replicate analysis of standard spiked at different concentrations was used to calculate the limit of detection (LOD) and limit of quantification (LOQ).

Half-life of atrazine

The half-life values of atrazine in different treatments were calculated from the slope of the regression equation using the below formula:

$$\text{Half Life} = \frac{\text{Log } 2}{\text{Slope of the equation}}$$

Results and Discussion

Persistence of atrazine (µg g^{-1}) in soil grown with maize

The duration in which herbicide endure active in the soil is called soil persistence or soil residual life [8]. According to Sondhia [9] herbicides persistence in the soil is described as half-life or period needed to debase 50% of the original molecule. Under the given optimised condition of HPLC, the retention time of atrazine was 3.29 minutes at 0.01 ppm (Figure 1). This is the amount of time that atrazine has spends on the column after it was injected. In other words, atrazine resolved at 3.29 minutes as a single sharp peak.

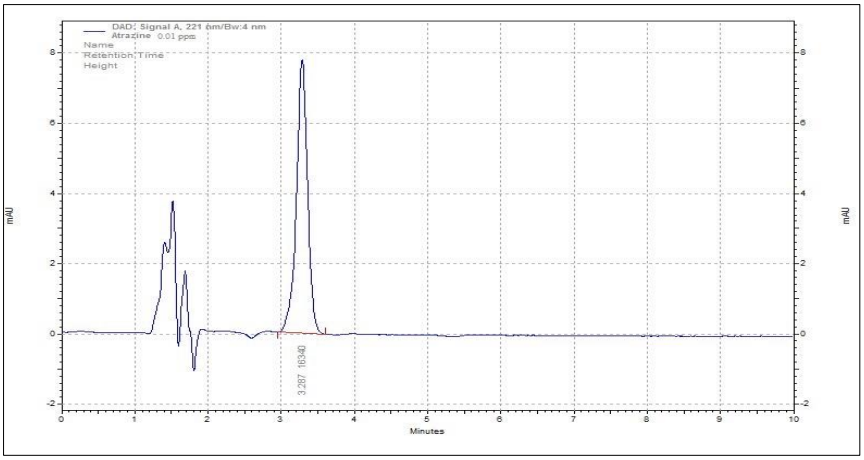

Fig 1: Standard chromatogram of atrazine at 0.01 ppm

The initial concentration of atrazine in the soil at 0 DAHA (2 hrs after application) ranged from 0.212 to 1.023 µg g^{-1} and from 0.260 to 1.203 µg g^{-1} across different doses of atrazine during 2019-20 and 2020-21 *Kharif* season respectively

(Table 1 and 2). In both years, the lower concentration was recorded at the lower dose (T_1: 0.50 kg a.i ha^{-1}) while the highest concentration was recorded at the higher dose (T_7: 2.00 kg a.i ha^{-1}). Furthermore, there was gradual reduction in concentration from 0 DAHA to 110 DAHA in all the treatments in both years. It is clear from the results that atrazine at recommended rate (0.50 kg a.i ha^{-1}) persisted in the soil up to 30 DAHA during both seasons hence left no residue in the post-harvest soil while it persisted up to 110 DAHA only at high treatment doses (T_5: 1.50 kg a.i ha^{-1}, T_6: 1.75 kg a.i ha^{-1} and T_7: 2.00 kg a.i ha^{-1}). The results clearly indicated that increasing the concentration of atrazine slows down its degradation period. Conforming to Gasic *et al*. [10], atrazine residues in the soil depends on the soil composition, pH, temperature, and soil humidity. Additionally, administered atrazine is subjected to sorption as well as diverse chemical and biological degradation mechanisms which advance the depletion of atrazine in the soil.

Table 1: Persistence of atrazine (µg g^{-1}) in soil during maize cropping period (*Kharif* 2019)

Trt	Days after herbicide application												
	0	**1**	**3**	**5**	**7**	**10**	**15**	**30**	**45**	**60**	**75**	**90**	**110**
T_1	0.212	0.196	0.181	0.152	0.139	0.099	0.056	0.015	BDL	BDL	BDL	BDL	BDL
T_2	0.325	0.283	0.275	0.240	0.218	0.178	0.110	0.029	BDL	BDL	BDL	BDL	BDL
T_3	0.433	0.385	0.371	0.303	0.291	0.255	0.211	0.106	0.012	BDL	BDL	BDL	BDL
T_4	0.580	0.536	0.506	0.413	0.338	0.272	0.250	0.226	0.060	0.015	BDL	BDL	BDL
T_5	0.657	0.613	0.556	0.497	0.461	0.381	0.325	0.253	0.130	0.028	0.021	0.015	0.008
T_6	0.807	0.797	0.657	0.577	0.553	0.443	0.408	0.299	0.140	0.106	0.089	0.038	0.008
T_7	1.023	0.857	0.822	0.765	0.695	0.625	0.583	0.488	0.294	0.217	0.172	0.130	0.009

Trt: Treatment, T_1: pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}, T_2: pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}, T_3: pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}, T_4: pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}, T_5: pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}, T_6: pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}, T_7: pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}, BDL – below detectable level (< 0.01 µg g^{-1})

Table 2: Degradation of atrazine (µg g^{-1}) in soil grown with maize during 2020-21 *Kharif* season

Trt	Days after herbicide application												
	0	**1**	**3**	**5**	**7**	**10**	**15**	**30**	**45**	**60**	**75**	**90**	**110**
T_1	0.260	0.216	0.182	0.171	0.133	0.127	0.053	0.021	BDL	BDL	BDL	BDL	BDL
T_2	0.367	0.316	0.289	0.275	0.254	0.181	0.144	0.038	BDL	BDL	BDL	BDL	BDL
T_3	0.476	0.424	0.383	0.370	0.335	0.273	0.167	0.126	0.089	BDL	BDL	BDL	BDL
T_4	0.623	0.561	0.503	0.479	0.416	0.384	0.333	0.296	0.172	0.042	BDL	BDL	BDL
T_5	0.741	0.595	0.539	0.487	0.465	0.437	0.394	0.301	0.215	0.055	0.046	0.029	0.008
T_6	0.867	0.771	0.745	0.628	0.565	0.524	0.410	0.304	0.239	0.133	0.118	0.073	0.009
T_7	1.203	0.923	0.759	0.676	0.567	0.543	0.459	0.378	0.326	0.278	0.230	0.185	0.010

Trt: Treatment, T_1: pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}, T_2: pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}, T_3: pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}, T_4: pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}, T_5: pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}, T_6: pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}, T_7: pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}, BDL – below detectable level (< 0.01 µg g^{-1})

Atrazine degradation in the soil followed first order kinetics during both *Kharif* seasons and the corresponding data fitting this order is represented in Table 3 and 4. The correlation coefficient (R^2) derived from the regression lines lies between 0.855 and 0.993 during *Kharif* season of 2019-20 and between 0.766 and 0.985 during 2020-21 season. Half-life values increased with increasing level of atrazine in both seasons. During 2019-20 *Kharif* season, calculated half-life ranged from 7.68 to 22.13 days across the different atrazine levels (Table 3) whereas during 2020-21 it ranged from 8.22 to 24.88 days (Table 4). During both seasons, higher rate of application (T_7: 2.00 kg a.i. ha^{-1}) recorded the highest half-life values (2019: 22.13 days and 2020: 24.88 days). This might be owing to delay phase of microbial activity at the inception of atrazine degradation. Furthermore, higher half-life at higher application rate could be attributed to the soil pH or toxicity to microbial activity. Tandon and Singh [11] have reported atrazine half-life of 16.4 days (soil pH 8.70) under application rate of 2.00 kg a.i. ha^{-1} under subtropical conditions in winter maize. Additionally, atrazine half-life of 14.4 days under soil pH 6.5 in subtropical soils under application rate of 2.00 kg a.i. ha^{-1}was reported by Wang *et al*. [12]. Soil pH has an influence in the persistence of herbicides mainly those that belong to the triazines and sulfonylureas group. These herbicides break down slowly in soils with higher pH especially above 7.0 [13]. Moreover, soil pH also influences adsorption of pesticides.

Table 3: Regression equation, correlation coefficient and half – life of atrazine in maize field during 2019-20 *Kharif* season

Treatments	Regression equation	R^2 value	Half-life (days)
T_1: pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}	y = -0.0392x + 2.3634	0.9932	7.68
T_2: pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}	y = -0.0348x + 2.5432	0.9872	8.65
T_3: pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}	y = -0.031x + 2.6849	0.9268	9.71
T_4: pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}	y = -0.0235x + 2.7618	0.9384	12.81
T_5: pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}	y = -0.0182x + 2.7997	0.977	16.54
T_6: pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}	y = -0.0156x + 2.8846	0.9631	19.30
T_7: pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}	y = -0.0136x + 3.0055	0.8548	22.13

Table 4: Regression equation, correlation coefficient and half – life of atrazine in maize field during 2020-21 *Kharif* season

Treatments	Regression equation	R^2 value	Half-life (days)
T_1: pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}	y = -0.0366x + 2.3897	0.9753	8.22
T_2: pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}	y = -0.032x + 2.5798	0.9846	9.41
T_3: pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}	y = -0.0164x + 2.6219	0.9361	18.36
T_4: pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}	y = -0.016x + 2.7792	0.9034	18.81
T_5: pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}	y = -0.0162x + 2.8348	0.972	18.58
T_6: pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}	y = -0.0142x + 2.9123	0.9222	21.20
T_7: pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}	y = -0.0121x + 2.9629	0.766	24.88

Persistence of atrazine (µg g^{-1}) in soil grown with cowpea

Persistence of atrazine (µg g^{-1}) in soil grown with cowpea during 2019-20 and 2020-21 *Rabi* seasons at 15, 30, 45, 60 days after sowing as well as at harvest was below detectable level (< 0.01 µg g^{-1}) as presented in table 5. Factors affecting herbicide persistence and concentration in the soil include microbial decomposition, chemical decomposition, soil adsorption, volatilization, photodecomposition, plant uptake and metabolism, leaching and surface runoff [14]. These processes could have been responsible for reducing the levels of atrazine in the soil [15] hence it was below detectable level during the growing period of cowpea.

Table 5: Persistence of atrazine (ppm) in soil in cowpea field during *Rabi* seasons

Trt	2019-20					2020-21				
	15 DAS	30 DAS	45 DAS	60 DAS	At harvest	15 DAS	30 DAS	45 DAS	60 DAS	At harvest
T_1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T_2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T_3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T_4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T_5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T_6	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
T_7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Trt: Treatment; T_1: pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}; T_2: pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}; T_3: pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}; T_4: pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}; T_5: pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}; T_6: pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}; T_7: pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}; BDL: below detectable level (< 0.01 µg g^{-1}); DAS: days after sowing.

Conclusion

Atrazine degradation in the soil followed first order kinetics during both *Kharif* seasons of the experiment. The half-life values of atrazine ranged from 7.68 to 22.13 days across the different atrazine levels during 2019 *Kharif* season and from 8.22 to 24.88 days during 2020 *Kharif* season. During both *Rabi* seasons persistence of atrazine in soil was below detectable level (< 0.01 µg g^{-1}). Hence, it can be concluded from this assessment that longer persistence of atrazine can be expected at higher application rates. Therefore, it is advised to apply atrazine at the recommended rate (0.50 kg a.i. ha^{-1}) which has showed shorter persistence in the soil during the experimental period.

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Conflicts of interest

No conflicts of interest have been declared.

References

1. Walker A. Evaluation of a simulation model for prediction of herbicide movement and persistence in soil. Weed Res 1987;27(2):143-152.
2. Sheets TJ. Persistence of triazine herbicides in soil. In *Residue Review* (eds. Gunther, F. A. *et al.*), Springer, New York 1970,287p.
3. Zhao X, Wang L, Ma F, Bai S, Yang J, Qi S. *Pseudomonas sp*, ZXY – 1 a newly isolated and highly efficient atrazine – degrading bacterium and optimization of biodegradation using response surface methodology. J. Environ. Sci 2017;54:152-159
4. Ghosh PK, Philip L. Environmental significance of atrazine in aqueous systems and its removal by biological processes: an overview. Glob. Nest J 2006;8:159-178.
5. Almeida Lage AL, Ribeiro JM, de Souza-Fagundes EM, Brugnera MF, Martins DCDS. Efficient atrazine degradation catalysed by manganese porphyrins: Determination of atrazine degradation products and their toxicity evaluation by human blood cells test models. J. Hazard Mater 2019,378.
6. Cheng M, Zeng G, Huang D, Lai C, Xu P, Zhang C, Zhu Y. Degradation of atrazine by a novel Fenton-like process and assessment the influence on the treated soil. J. Hazard Mater 2016;312:184-191.
7. Moinuddin G, Kundu R, Jash S, Sarkar A, Soren C. Efficacy of atrazine herbicide for maize weed control in new alluvial zone of West Bengal. J. Exp. Biol. and Agric. Sci 2018;6(4):707-716.
8. Reddy SR. Introduction to Agronomy and Principles of Crop Production. Kalyani Publishers, Ludhiana 2014.
9. Sondhia S. Herbicides residues in soil, water, plants and non-targeted organisms and human health implications: an Indian perspective. Indian J Weed Sci 2014;46(1):66-85.
10. Gasic S, Budimir M, Brkic D, Neskovic N. Residues of atrazine in agricultural areas of Serbia. J. Serbian Chem. Soc 2002;67:887-892.

11. Tandon S, Singh A. Field dissipation kinetics of atrazine in soil and post-harvest residues in winter maize crop under subtropical conditions. Chem. Ecol 2015;31(3):273-284.
12. Wang YS, Duh JR, Liang YF, Chen YL. Dissipation of three s-triazine herbicides, atrazine, simazine and ametryn in subtropical soils. Bull Environ. Contam. Toxicol 1995;55(3):351-358.
13. South DB. Weed control in Southern Hardwood Nurseries. In National Proceedings, Forest and Conservation Nursery Association. Gen. Tech. Rep. RM-257. Fort Collins, CO: U.S. Department of Agriculture, Forest Services, Rocky Mountain Forest and Range Experiment station 1994,31-37p.
14. Devlin DL, Peterson DE, Regehr DL. Residual herbicides, degradation and recropping intervals. Kansas State University 1992.
15. Muoni T, Rusinamhodzi L, Mabasa S, Rugare JT, Thierfelder C. Does the use of atrazine in maize grown under conservation agriculture adversely affect soybean productivity in maize-soybean rotation in Zimbabwe? J. Agric. Sci 2014;6(7):294-302.