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Residues, persistence and dissipation pattern of imazethapyrin *Typic Usrtochrept* soil of Indo-Gangetic Plains

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ABSTRACT

Imazethapyr is widely used in soybean and very recently recommended for control of wide spectrum of weed species in rainy season pulse crops. Pot and field studies were conducted to evaluate dissipation pattern and the residues of imazethapyr in the soil, mungbean straw and grain continuously for three consecutive years of 2014-2017. Imazethapyr was applied at its recommended dose of 100 g/ ha, as a postemergence (21 days after sowing) to control weeds in rainy season mungbean. In field experiments, imazethapyr residues were found far below to its prescribed MRL value (0.1mg/g).The residue of herbicide in field soilwas found 0.00043, 0.00038, 0.00027, 0.00021, 0.00016 and 0.00012 mg/g of soil, respectively at intervals of 2hrs, 5th, 15th, 25th, 35th, and 45th days of herbicide spray whereas, in pots ranged between 0.0082 to 0.0042mg/g of soil, respectively between the time period of 2hours to 70 days of herbicide application. The plant and grain samples were foundal most free of residue. The degradation of imazethapyrin soil and in pot studies was found to operate as per first order kinetic equation *viz.*, [dMi/Dt=K (M_a-M_i)]. Based on residue data obtained in both of the experiments i e field and pots, it was observed that in light textured soil, 50% of the herbicide got dissipated within a period of 26 days of herbicide spray (calculated $T_{1/2}$ =26 days, average K=2.74X10^{-2}), whereas, in pots (soil contain comparatively more clayand organic carbon), the 50% concentration of the herbicide was found to persist up to a period of 82 days (calculated $T_{1/2}$ =82 days, k=8.59X10^{-3}) and 90% herbicide got decayed within 268 days. Based on dissipation studies and calculated average K=2.74X10^{-2}, the effective period (T_{eff}.) in field was calculated as 15-20 days, which suggest imazethapyr can only provide protection to crop against weed up to a maximum period of 15-20 days.

***Keyword*:** Dissipation, Imazethapyr, Mungbean, Persistence, Residues

Weeds are major constraints in achieving yield potentials of pulse crops. Especially during rainy season, weed control is a great challenge to pulse growing farmers. Pulse crops are considered as poor competitors with weeds owing to be of their slow initial growth. Traditionally, hand weeding is a common practice to remove weeds from pulse crops. At present, because of the scarcity of labor as well as the cost effectiveness of the system limit the use of hand weeding in pulses. For this reason, growers either avoid fields with a history of broadleaf perennial weed problems or look for some alternative options. Keeping in view of this, presently, few herbicides are registered for managing weeds in pulse crops. In this group Imazethapyr is considered a most effective chemical option for weed control in these crops because of its extremely effective weed control capacity *vis a vis* good crop tolerance in *Kharif* pulses and other leguminous crops (Loux*et et al.* 1989, Sondhia 2013, Kumar *et al.* 2013&2016). The herbicide can be applied as pre plant incorporated, pre emergence, and post-emergence to control grasses and broadleaved weeds in pulse crops (Herbicide handbook 1989, Thomson 1993, Anon 2006). Imazethapyr (5-ethyl-2-[(*RS*)-4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl]nicotinic acid) belongs to the imidazolinone group with a toxicity class of III and is used as a selective herbicide for the control of many broad spectrum of weed species (Thomson 1993, Arora and Sondhia 2013,Kumar *et al.* 2016). It acts by inhibiting the production of three branched-chain aliphatic amino acids *viz*., isoleucine, leucine and valine by disrupting the acetohydroxy acid synthase (AHAS) pathway. This inhibition causes a disruption in protein synthesis which ultimately leads to interference in DNA synthesis and cell growth. Under field conditions, the herbicide is known to dissipate inthe soil by microbial degradation and photolysis (Stougaard1990) however the organic matter and pH were blamed to affect significantly of imazethapyr behavior in soil (Sondhia 2013, Wehtje *et al.* 1987). Though, presently herbicides are proving effective tools to control weeds yet there has been an over reliance on their use may led to ever increasing weed resistance around the world and severe environmental hazards. In case of imazethapyr,inspite of having its extreme effect on weeds at very low concentration, it was also reported for its severe environmental concerns. Although Imidazolinone group of herbicides are known for their weakly adsorption by soil (Gan*et al.* 1994, Mangel 1991) and not readily leach under field conditions (McDowell 1997) yet some of the reports revealed leaching of imazethapyr below 25 cm in soil during fifth month (Sondhia 2013, Battaglin *et al.* 2000). As a result of leaching and runoff, imazethapyr residues were reported in streams and rivers in the Midwestern USA at concentrations above the maximum residue limits in 71% of samples (Basham *et al.*1987). This kind of leaching and persistence of the herbicide may not only damage subsequent crops in rotation but also cause health problems to living beings. Not only this, the residual effect of herbicide is also considered a very severe concern for the Rhizobial and other microbial activities (Zhang *et al.* 2010). Since,

presently herbicidal control of weeds is gaining much importance therefore; it has become very much imperative to have information on their residual values as well as the effect of secondary products formed over their degradation. The information are very much essential for both *i.e* the promotion of herbicidal weed control as well as the modeling of the fate and effects of these chemicals in the environment. Thus, this study was undertaken to determine terminal residues and degradation pattern of imazethapyr in soil, mungbean grain, and straw by following its post emergence application to mungbean crop.

MATERIALS AND METHODS

Study design: The study was meticulously planned to determine the residues of imazethapyr in the soil, mungbean grain, and straw after post emergence application of herbicide in the mungbean crop. Field experiments were conducted for three years 2014-2017 at field no B-13 of New Research Campus of Indian institute of Pulses Research, Kanpur, India. Soil physicochemical characteristics of both of the IIPR farms are given below in Table 1. The IIPR research farms are located at 26° 27/ N latitude, 80° 14/ E longitude at an altitude of approximately 152.4 m (508 ft) above mean sea level. Kanpur is located in the centre of Uttar Pradesh and fall in the agro climatic region of central Zone of the state. This agro climatic region is one of the most fertile tracts of Ganga and Jamuna basins. The soils of experimental site come under taxonomical class *Typic Usrtochrept* with sandy loam texture. The climate is tropical sub-humid, receives annual rainfall of 722 mm and mean annual maximum and minimum temperature is 33.0 and 20.0°C, respectively. Treatments comprised of pendimethalin @ 1.0 kg/ha *fb* imazethapyr @ 100 g/ha, weedy check and weed free. The experiment was conducted under randomized block design with 3 replications. Mungbean variety 'Samrat' (PDM 139) was used for the study which has crop duration of approximately 60 days. Mungbean was sown during 20-22 July in all the three years. Plant to plant distance was maintained ~10 cm with a row spacing of 30 cm. DAP was applied 100 kg/haat the time of seedbed preparation. Due to rainy season, sufficient soil moisture was remained in the field at the time of sowing to ensure proper germination. Post-emergence herbicides were applied at 20-21 days after sowing (DAS) whereas pendimethalin was applied as pre-emergence within 24 hours of sowing. Irrigation was not required due to sufficient rainfall during crop growth period. Plant protection measures were followed as per recommendation for the region.

Sampling: From field experiment, soil samples were collected periodically starting from just after 2hrs of spray subsequently at 5th day and thereafter a regular interval of 10 days viz**.** 2h**,** 5, 15, 25, 35 and 45 days of herbicide spray. For the determination of terminal residues, soil samples were also collected after harvest (60-65 days, which is equivalent to 40-45 days after herbicide application). Samples were taken randomly from ten to fifteen different places of imazethapyr treated plots. Soil cores of each approximately 0.5 kg of soil were randomly taken from untreated and treated plots using a soil auger to a depth of 15 cm from the surface in each location. Pebbles and other unwanted materials were removed manually. The bulk soil samples from each location were air dried under shade, powdered, and passed through a 3-mm sieve. Approximately 0.5 kg of representative mungbean plant samples were also collected randomly from the imazethapyr-treated and control plots at the time of harvest (60-65 days). Grains were separated out from the plants samples. The straw samples were cut in small pieces and air-dried under shade. Mungbean grains and straw samples were then grounded to fine powder by using a mechanical grinder. For persistence and degradation studies, pot experiments were conducted under control conditions by externally adding the required amount of Imazethapyr technical (1 mg/ 200gsoil) to the soil of pots. Pots were filled with 3 kg of soil collected from main research farm having soil physicochemical properties as described in table-1. From treated pots 50g of soil samples were taken out periodically, starting from just after 2hours of mixing of Imazethapyr and then to a regular interval of 10 days (10, 20, 30, 40, 50, 60 and 70 days).

Extraction and cleanup: Collected soil and plant samples were processed for extraction and cleanup as per methodology described by Sondhia (Sondhia 2013). Representative soil (20 g) and plant samples (grain and straw) were placed in Erlenmeyer flasks (250 ml) and extracted with 0.5 N NaOH (50 and 100 ml, respectively) in a horizontal shaker (repeated twice). Additional methanol (50 ml) was added to the flask, which was then shaken vigorously, filtered, and adjusted to a pH to 2 with 6 N hydrochloric acid. The content was transferred to a separatory funnel (500 ml) and partitioned with dichloromethane (50 ml, twice). The lower dichloromethane layer was collected, combined and dried on anhydrous Na_2SO_4 and passed through activated charcoal. The solvent was evaporated completely to dryness at 45°C temperature by using a rotary vacuum evaporator. Finally residues were dissolved in 5 ml of methanol and subjected to cleanup. These samples were cleaned on a glass column (10 cm×2 cm i.d.) packed with Celite (1 g) and activated charcoal (0.25 g) between anhydrous sodium sulfate (2 g) at each end. The column was conditioned with methanol. The concentrated extract was added at the surface of the column and eluted with methanol and water (60:40 v/v). Elutes were collected, and the solvent was evaporated completely using a rotary vacuum evaporator. Residues were again dissolved in 5 ml of methanol and filtered through Pall Nylon 0.45-µm filter paper and then passed through MERCK, LiChrolut*RP-18, 1000mg columns prior to HPLC analysis.

Instrumentation: Imazethapyr residues were analyzed with a Shimadzu HPLC coupled with a diode array detector

Table 1. Soil physicochemical characteristic of experimental sites

Soil characteristics	Field location			
	IIPR main farm	IIPR, New research farm	Experimental field No. B 13	Soil filled in pots
pH	7.79	8.33	8.45	7.75
EC (dS/m)	0.131	0.154	0.23	0.130
Available N (kg/ha)	250.6	225	225.0	255.0
Available P (kg/ha)	17.4	14.3	13.41	18.0
Available K (kg/ha)	188.2	72.5	68.32	179.0
Organic carbon (%)	0.471	0.345	0.159	0.479

(DAD) with $\ddot{e}_{max}$ of 230 and 254 nm for detection purposes. A Phenomenex C-18 (ODS) column (250×4.6 mm) and methanol: water (70:30 v/v) as a mobile phase at a flow rate of 0.9 ml/min were used to separate imazethapyr residues. A 20-µL aliquot of the samples and standard were injected into the column with a micro syringe.

Residue determination: Quality control (QC) and quality assurance (QA) procedures were adopted since collecting the samples and up to extraction, and analytical stages of the studies to determine and maintain the quality of the analytical data. During the sampling stage, control samples were also collected from untreated plots. Imazethapyr residues were determined by proper cleaning of soil, grain and straw samples. For recovery check the spiked samples (mungbean grains, straw, and soil) were fortified by externally adding the known concentration of imazethapyr standard solutions to ensure the herbicide concentrations in the samples in the range of 0.01 to 0.5 µg/g. Thereafter the extraction and cleanup processes as described above were adopted for calculation of percent recovery of imazethapyr from the fortified samples. For obtaining calibration curve a known concentrations of imazethapyr pure technical viz., 0.01, 0.05, 0.5, 1.0, and 5.0 µg/ml were prepared in methanol by diluting a stock solution of 1000µg/ml prepared from the same standard (Table 2). For this purpose certified reference imazethapyr (Accu Standard, USA) was used (Fig. 1 and 2). The concentration of

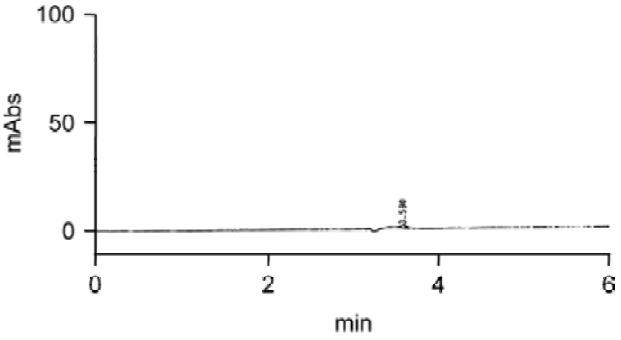
Table 2. Calibration of imazethapyr standard at concentration level of 0.01 to 5 µg/ml

Injected concentration of imazethapyr (µg/ml)	Av. area (mabs)[a)]	Std. deviation
5	913940	±51812.91
1	275960	±10459.28
0.5	197084	±5466.37
0.1	54198	±937.67
0.01	21434	±752.35

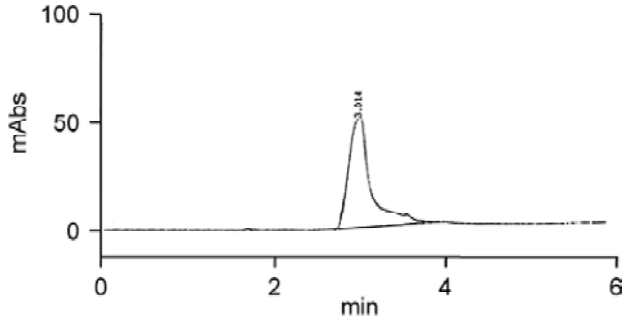
imazethapyr was determined by comparing the peak area of the samples and calibration curves of five levels of standards and the percent recovery was calculated is per formula i.e percent Recovery = Recovered Concentration/ Fortified Concentration × 100. A reporting limit of 0.01 µg/g was used for the calculation. The limit of determination (LOD) [estimated to be three times the background noise] and the limit of quantification (LOQ) [estimated to be 10 times the background noise] were found to be 0.001 and 0.01 µg/ml, respectively (Sondhia2008).

RESULTS AND DISCUSSION

Recoveries and detection limit: In this study, the parameters accuracy, precision, linearity and limits of detection (LOD) and quantification (LOQ) were considered to ensure analysis credibility. The accuracy of the method was determined by recovery testsusing samples spiked at concentration levels of 0.01 and 0.5 µg/ml. Linearity was determined by different known concentrations (0.01, 0.05 0.1, 0.5, 1.0 and 5.0 µg/ml) those prepared by diluting the stock solution of 1000 µg/ml. The limit of quantification of imazethapyr in soil, mungbean grain and straw was workout and found 0.01 µg/g with a signal to noise ratio of 3:1. A calibration equation of analytical calibration graphs was received by plotting peak areas on the *y* axis against concentrations of imazethapyr on the *x* axis within a range of 5 to 0.01 µg/ml which revealed good linearity. At this concentration range, the correlation coefficient was found nearly to 0.99. On the instrumental conditions explained above under the head of materials and method section the retention time of imazethapyr was found to be approximately of 3.345 min. Imazethapyr recoveries varied from 83–77%,



Imazethapyr standard 1. Fig. 0.01 ppm.



Imazethapyr standard 5 ppm. 2. Fig.

Fig. 1&2. Chromatogram of Imazethapyr standard at concentration 0.01 and 5 ppm

88–74%, and 84–74% for soil, mungbean grains, and mungbean straw, respectively fortified with 0.01 and 0.5 µg/g of imazethapyr (table 3). The recovery for mungbean grain and straw was considered acceptable up to fortification level of 0.01 µg/g. Hence, recoveries of imazethapyr from various matrixes at different concentration levels were found satisfactory.

Periodical and Terminal residues of imazethapyr: Field experiments, conducted to study the residue level and persistence of imazethapyr applied to mungbean crop in sandy clay loam soil of taxonomical class *TypicUsrtochrept* revealed residues far below then its prescribed MRL value at any point of time. The residue level of imazethapyr in soil, mungbean grain and straw were analyzed continuously for three years and the results revealed that the concentration of imazethapyr in soil decreased with time and at harvest, residues were below the detectable limit. The average of three years of residue level of imazethapyr in soil was found 0.00043, 0.00038, 0.00027, 0.00021, 0.00016 and 0.00012 mg/g of soil, respectively at intervals of 2hrs, 5th, 15th, 25th, 35th and 45th days of herbicide spray in field experiment whereas in pots (kept in control condition and filled with the soil contained comparatively more clay and organic carbon and lesser pH) the residues of herbicide was found to range between 0.0082 to 0.0042mg/g of soil, respectively between the time period of 2hours to 70 days of herbicide application (table 5). Compare to the soil in pots less imazethapyr residue was detected in the open field experiment at soil. The reason may be that Imazethapyr is known to have low K_{oc} values (19.8–83.9), which leads to its little adsorption for any kind of the soils and a very high mobility and consequently a high potential to leach (Arora and Sondhia 2013, Sondhia 2013). Since experiments were conducted during July to September and between this periods occurring of frequent and occasionally heavy rainfall is common phenomenon of this region which might have resulted in leaching of highly soluble imazethapyr (solubility in water 1.4-3.7g/l) after application in mungbean crop. The leaching of imazethapyr under the influence of heavy rainfall was also reported by Sondhia (2013) in soybean experiments. This may also be the one of important reason of having very little residues of the herbicide in the soil at harvest. The same is also supported by Sondhia (2013), Barnes and Lavy (1991), Goetz *et al.* (1986) and Sondhia (2008). Less adsorption and a slightly alkaline pH (>8.0) also favored the fast dissipation of imazethapyr residue in the surface soil (0–15 cm) however, under reported agro climatic conditions imazethapyr residues in the soil showed a fast degradation pattern as against its reported maximum soil photolysis half-life of 33 months (N. Y. S. Imazethapyr: DEC Letter 2015). Soil, seed and straw samples taken at harvest (70-75 day of sowing) were force from residue of the herbicide (table 4). Though at this application rate of herbicide viz., 100g/ha Sondia (2008) reported a post-harvest residue level of 0.008, 0.102 and 0.301 µg/g in soil, grains and straw of soybean croprespectively. Some researchers reported imazethapyr residues in mature plants of some crops. In this respect Mallipoodi *et al.* (1994) demonstrated nearly 0.08 and 0.02 ppm of imazethapyr residues in mature stalk and seed of corn despite of rapid metabolic procedures in corn plant. The herbicide was reported to get metabolized in corn plants through oxidative hydroxylation at the á-carbon atom of the ethyl substituent on the pyridine ring to yield á-(hydroxylethyl)-imazethapyr.

Persistence and Dissipation pattern: The persistence or dissipation of a chemical is mainly controlled by

Table 3. Recovery of the imazethapyr from soil, grain and straw

Matrix	Fortified concentration (µg/g)	Fortified concentration (µg/g)	Concentration found (µg/g)[a)]			Recovery (%)			Average recovery
			R1	R2	R3	R1	R2	R3	
Soil		0.50	0.420	0.400	0.430	84.0	80.0	86.0	83.33
		0.01	0.0079	0.008	0.0071	79.0	80.0	71.0	76.66
Mungbean grain		0.50	0.460	0.470	0.400	92.0	94.0	80.0	88.66
		0.01	0.0075	0.007	0.0078	75.0	70.0	78.0	74.33
Mungbean straw		0.50	0.435	0.400	0.420	87.0	80.0	84.0	83.66
		0.01	0.0078	0.0075	0.007	78.0	75.0	70.0	74.33

Table 4. Periodical and Terminal residues of imazethapyr in mungbean soil, grains, and straw at different times

Sampling at time	Residue level of herbicides (mg/g) at λ max 254								
	Soil (NRF & main farm)			Straw (NRF & main farm)			Grain (NRF & main farm)		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
2 hrs.	0.00041	0.00041	0.00047	-	-	-	-	-	-
5 days	0.00038	0.00031	0.00045	-	-	-	-	-	-
15	0.00029	0.00025	0.00027	-	-	-	-	-	-
25	0.00023	0.00018	0.00023	-	-	-	-	-	-
35	0.00021	0.00011	0.00015	-	-	-	-	-	-
45	0.00018	0.00009	0.00011	-	-	-	-	-	-
55(Terminal residue)	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	ND	ND	ND

[a)]Limit of quantification (0.01 µg/g).
(ND) not detected

Table 5. Dissipation pattern and effective time

Sampling (at day)	Imazethapyr residue (mg/g soil) at $?_{max}$ 254 in field					Imazethapyr residue (mg/g soil) at $?_{max}$ 254 in pot				
	Residue level	Dissipation pattern				Residue level	Dissipation pattern			
		% dissipation	rate constant (K)	$T_{1/2}$ (days)	Effective time ($T_{eff.}$) & persistence (90%deg.)		% dissipation	Rate constant (K)	$T_{1/2}$ (days)	$T_{eff.}$ & persistence (90%deg.)
2hrs.	$4.3x10^{-4}$	0.00	0.00	0.00	Effective time of herbicide calculated on the bases of concentrations. between 100-75 g/h by taking average K-$2.74x10^{-2}$ is= 15-20d & Persist=84d	$8.2x10^{-3}$	0.00	Average k $8.59x10^{-3}$	Average=82d	Effective time of herbicide calculated on the bases of concentrations. between 100-75 g/h by taking average K-$8.59x10^{-3}$ is= 30-35d & Persist=268d
5th	$3.8x10^{-4}$	18.00	$2.5x10^{-2}$	28						
10th	-					$7.6x10^{-3}$	4.00	$7.60x10^{-3}$	92	
15th	$2.7x10^{-4}$	37.00	$2.8x10^{-2}$	25				-		
20th	-					$6.9x10^{-3}$	16.00	$8.73x10^{-3}$	80	
25th	$2.1x10^{-4}$	51.00	$2.8x10^{-2}$	25				-		
30th	-					$6.4x10^{-3}$	22.00	$8.26x10^{-3}$	84	
35th	$1.6x10^{-4}$	63.00	$2.8x10^{-2}$	25				-		
40th	-					$5.8x10^{-3}$	29.00	$8.65x10^{-3}$	81	
45th	$1.2x10^{-4}$	72.00	$2.8x10^{-2}$	25				-		
50th	-	-		Average=26 days		$5.4x10^{-3}$	34.00	$9.49x10^{-3}$	74	
60th	-	-	Average k $2.74X10^{-2}$			$5.1x10^{-3}$	38.00	$7.91x10^{-3}$	88	
70th	-	-				$4.2x10^{-3}$	49.00	$9.55x10^{-3}$	73	

environmental conditions that include climate, soil physicochemical properties and microbial activity in the soil vis a viscrop management practices. In present experiments, the degradation of imazethapyr, under mentioned soil conditions was found to operate as per first order kinetic equation *viz.*, $[dMi/Dt=K(M_{á}-M_{i})]$.The analysis of imazethapyr residue data revealed that in NRF field where soil contained lesser clay and organic matter, more sand and silt particles with high pH (nearly to 8.5), the 50% of the herbicide got dissipated within a period of 26 days of application (calculated $T_{1/2}$ =26 days average K =$2.74X10^{-2}$), whereas, in pots soil which containing comparatively more clay content and organic carbon with pH less than 8.0andlesser sand particles, the 50% concentration of the herbicide was found to persist up to a period of nearly 82 days (calculated $T_{1/2}$ =82 days, k=$8.59X10^{-3}$) and 90% got decayed within a period of 268 days. Our results are in close agreement with previous findingsof other workers. In this context Goetz and Lavy(1990) reported imazethapyr half life in different soil and various environmental conditions between 78-318 days whereas, Tu*et al.* (2001) showed half lives ranging from one to five months (30- 150 days) and Wang *et al.*(2005) reported 22 to 36 days. In laboratory experiments Vischetti and Goetz derived half life of imazethapyr nearlyto 65 days. Based upon the estimated half lives, imazethapyr dissipation was found more pronounced in field with rate constant $2.74x10^{-2}$ as compare to the pot experiments (rate constant $8.59x10^{-3}$) conducted in laboratory. Aichelle and Penner (2005) also reported greater dissipation rates of imazaquin and imazethapyr in field experiments as compare to laboratory studies. Compare to pots, faster dissipation of the herbicide in field may be understood by quicker removal of herbicide by the mechanism of leaching under rains and microbial degradation in addition to the difference in soil physicochemical properties and the exposed sun light (photo-degradation). Since, imazethapyr is well known to have low K_{oc} values and high water solubility properties therefore, may leach easily in soil below 40 cm layer. O'Sullivan *et al.* (1998) also demonstrated the marked effect of rainfall on imazethapyr persistence and concluded that the herbicide was lost from the profile either by leaching to below 40 cm or by microbial breakdown because the wet situation is more conducive to growth as well as the activity of microbes in the topsoil. But in contrary to that, Johnson *et al.* (2000) reported that imidazolinone leaching in field studies was minor or if leach the concentrations were below detectable levels. As far as soil physicochemical properties concern, Mangles (1991) demonstrated that the sorption of imidazolinones decreased with an increase in soil pH toward 7, which favored leaching. He demonstrated five different charged species of Imidazolinonesat various soil pH. If the soil pH is lowered from 6 to 3, the species predominating goes from a largely unsorbed anionic form to a form which is mostly uncharged (sorbed). The amount of sorption is also determined by the amount of organic matter present in soil. The high organic content in soil favored sorption of herbicide. Based on dissipation studies and calculated average K=$2.74X10^{-2}$, the effective period ($T_{eff.}$) in field calculated by taking account of the initial concentration i.e. 100g/ha at day 1 then come down to 75g/ hawas found to be nearly 15-20days which suggest that once spray, the herbicide can only provide protection to crop against weed up to a maximum period of 15-20 days in soil with properties as explained above. These results suggest that there is less risk of imazethapyr residue for both i.e the human health point of view as well as the carryover effect to succeeding crops. Similar conclusions were also reached by Johnson and Talbert (1996).

Finally, it can be concluded that soil with an alkaline pH and less adsorption capacity in totality may leads to less terminal imazethapyr residues. In present experiments the terminal imazethapyr residue in plant parts and seed was not detected however the maximum residue limit in plant parts and seed is (0.1 mg/kg) as set by the U.S.A. and some European countries (Anonymous 2006).

REFERENCES

Aichele TM and Penner D. 2005. Adsorption, desorption, and degradation of imidazolinones in soil. Weed Technology **19:** 154-159.

Anonymous. 2006. Regulations amending the food and drug regulations (Schedule 1454, imazethapyr), Part 1: Additional MRLs for chemicals with currently established MRLs on other food commodities. Canada Gazette **140:** 19.

Arora A and Sondhia S. 2013. Persistence of imazethapyr residues in soybean and soil. Indian Journal of Weed Science **45:** 226-227.

Barnes CJ and Lavy TL. 1991. Injury and yield response of selected crops to imazaquin and norflurazon residues. Weed Technology **5:** 598-606.

Basham GW, Lavy TL, Oliver LR and Scott HD. 1987. Imazaquin persistence and mobility in three Arkansas soils. Weed Science **35:** 576-582.

Battaglin WA, Forlong ET, Burkhardt MR and Peter CJ. 2000. Occurrence of sulfonylurea, sulphonamide, imidazolinone, and other herbicides in rivers, reservoirs and ground water in the Midwestern United States. Science of the Total Environment **248:** 123-133.

Gan J, Weimer MR, Koskinen WC, Buhler D, Wyse DL and Becker RL.1994. Sorption and desorption of imazethapyr and 5-hydroxyimazethapyr in Minnesota soils. Weed Science **42:** 92-97.

Goetz AJ, Lavy T, Land G, bur EE. 1990. Degradation and field persistence of imazethapyr. Weed Science **38:** 421-428.

Herbicide Handbook of the Weed Science society of America. 1989.(ed) Humburg NE, Colby SR,Lym RG, Hill ER, Mc Avoy WJ, Kitchen LM and Prasad RP. Weed Science Society of America, Champaign, Illinois, Sixth Edition. 301p.

Imazethapyr NYS DEC Letter 2015. http://pmep.cce.cornell.edu/profiles/herb-growthreg/fattyalcohol-monuron/imazethapyr/imazethapyr_let_800.html (Accessed 25 May 2015).

Johnson DH and Talbert RE. 1996. Cotton (*Gossypium hirsutum*) response to imazaquin and imazethapyr soil residues. Weed Science **44:**156-161.

Johnson DH, Shaner DL Deane, J Mackersie LA and Tuxhorn G. 2000. Time-dependent adsorption of imazethapyr to soil. Weed Science **48:** 769-775.

Kumar N, Hazra KK, Singh MK, Vankatesh MS, Kumar L, Singh J and Nadrajan N. 2013. Weed management techniques in pulse crops. Indian Institute of Pulses Research, Kanpur. Technical Bulletin **10**: pp: 1-47.

Kumar N, Nath CP, Hazra KK, and Sharma AR. 2016.Efficient weed management in pulses for higher productivity and profitability. Indian Journal of Agronomy **61(4):** 5199-5213.

Loux MM, Liebl RA andSlife FW. 1989.Adsorption of imazaquin and imazethapyr on soils, sediments, and selected adsorbents.Weed Science **37:** 712-718.

Mallipuddi NM, Lee A,Fiala R,daCunha AR and Safarpour M. 1994.Metabolism of Imazethapyr (AC 263499) Herbicide in Corn.Journal of agricultural and food chemistry **42:** 1213-1218.

Mangels G. 1991. Behavior of the imidazolinone herbicide in soil-a review of the Literature in The Imidazolinone Herbicides, Shaner DL and O'Connor SL, Eds., pp. 191-209, CRC Press, Boca Raton, FL, USA,

McDowell RW,Condron LM, Main BE and Dasgheib BF. 1997.Dissipation of imazapyr, flumetsulam and thifensulfuron in soil. Weed Research **37:** 381-389.

O Sullivan J, Thomas RJ andBouw WJ. 1998. Effect of imazethapyr and imazamox soil residues on several vegetable crops grown in Ontario. Canadian Journal of Plant Science **78:** 647-651.

Sondhia S. 2008. Determination of imazosulfuron persistence in rice crop and soil. Environmental Monitoring and Assessment **137:** 205-211.

Sondhia S. 2008. Persistence of metsulfuron-methyl in wheat crop and soil.Environmental Monitoring and Assessment **147:** 663-669.

Sondhia S. 2013. Evaluation of imazethapyr leaching in soil under natural rainfall conditions. Indian Journal of Weed Science **45:** 58–61.

Stougaard RN, Shea PJ and Martin A R. 1990. Effect of soil type and pH on adsorption, mobility and efficacy of imazaquin and imazethapyr. Weed Science **36:**67–73.

Thomson WT. 1993.Agricultural Chemicals. Book II, Herbicides," Thomson Publications, Fresno, CA, (USA). 310.

Tracy MA and Donald P. 2005. Adsorption, Desorption, and Degradation of Imidazolinones in Soil1. Weed Technology **19:** 154-159.

Tu M, Hurd C and Randall JM. 2001. Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas. The Nature Conservancy, http://tnc weeds.ucdavis.edu, version: April 2001.

Wang X, Zhou SM and Fan D. 2005.Biodegradation of imazapyr in typical soils in Zhejiang Province, China. Journal of Environmental Sciences**17:** 593-597.

Wehtje R, Dickens J,WilcutW and Hajek BF.1987. Sorption and Mobility of Sulfometuron and Imazapyr in five alabama soils. Weed Science **35:** 858–864.

Zhang C, Xu J, LiuX, Dong F,Kong Z, Sheng Yu and ZhengY. 2010. Impact of imazethapyr on the microbial community structure in agricultural soils. Chemosphere **81:** 800-812.