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RESEARCH ARTICLE

Dissipation kinetics and residues of pendimethalin in soil, straw and grain of rainy season greengram

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ABSTRACT

Pendimethalin [N-(1-ethylpropyl)-3, 4 dimethyl 2, 6 dinitrobenzenamine], is being used for control of majority of grasses and broad-leaf weeds in crops such as peas (*Pisum sativum* L.), rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), soybean (*Glycine max* L. merr.), and vegetables. Dissipation pattern and the residues dynamics of the herbicide in the soil, greengram straw and grain was determined by conducting field and pot experiments during 2017-2019 utilizing the doses of 1000 g/ha for field study and 1 mg/20 g soil for pots. The residue level of pendimethalin in soil were 0.088, 0.080, 0.075, 0.065, 0.056 and 0.048 mg/g at 2, 5, 15, 25, 35 and 45 days, respectively after herbicide application (DAA) in field that had gone down to below detectable level at the time of harvest (65-70 days). However, greengram plants and seeds, at time of harvest, were found free from the pendimethalin residues. The dissipation of pendimethalin in field and in pots was found to operate as per first order kinetic equation [$dC_0/dt=K(C-C_0)$], therefore, based on dissipation rate constant (K) values, *viz.* 1.36 x 10^{-2} (field) and 1.11x10^{-2} (pot), the half-lives ($T_{1/2}$) of pendimethalin were calculated as 52 and 62 days in field conditions and pot culture, respectively. The effective period ($T_{eff.}$) with respect to weed control was worked out as 21 and 26 days for field and pot experiments, respectively by assuming the concentration of herbicide in field between 1000-750 g/ha. Therefore, this study suggests that the herbicide can only provide effective protection to crop against weed up to a maximum period of 20-25 days in sandy clay loam soil of taxonomical class *Typic Usrtochrept.*

Keywords: Dissipation kinetics, Greengram, Pendimethalin, Persistence, Residues

INTRODUCTION

Weeds are major constraints in getting maximum yield potentials of pulse crops. In India, yield losses due to weeds are being roughly estimated as 32–35% in crops such as cereals, pulses and oilseeds (DWSR 2018, Kaur *et al.* 2010). In the current scenario, relying on herbicides for an effective and timely weed management especially in crops like pulses is a practical and economical option as opined by Kraehmer (2012), Kraehmer *et al.* (2014). Among the herbicides used in pulse crops, pendimethalin [N-(1-ethylpropyl)-3, 4 dimethyl 2, 6 dinitrobenzenamine], is utilized extensively as a pre-emergence herbicide for control of a majority of grasses and broad-leaf weeds. Though, in one way, herbicides can be considered as an effective tool for weed management but on the other hand their residues were reported to cause numerous environmental problems (Kim *et al.* (2017, Sankhla *et al.* 2018). Herbicides may not only contaminate the surface and ground water but also remain on the soil surface and potentially affect the quality and yield of the succeeding crop. Presence of undesirable residues of herbicides in edible parts of plant also concerns a severe problem for human being (Bruggen *et al.* 2018).

Therefore, keeping in view of adverse impacts of herbicides, it is imperative to make an understanding of their dissipation and movement in fields prior to their recommendation for extensive use. Though, the pendimethalin is reported to possess moderate persistence and relatively immobile properties (Tsiropoulos and Miliadis 1998, Triantafyllidis *et al.* 2009), however based on various field experiments few report have also been published indicating appreciable persistence of this herbicide in various soils (Chopra *et al.* 2015, Sondhia 2012 and 2013b, Dennisc and Dale 2014). Pendimethalin persistence in soil is reported to depend largely on the environmental conditions, cultivation practices, soil

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type, soil temperature and moisture conditions as well as the photodecomposition (Maria and Andrzej 2012) besides a great portion of herbicide in field also got decayed by microbial action (Lee *et al.* 2004, Kocarek *et al.* 2016, Sondhia *et al.* 2016). Though the information regarding the persistence and residues situation of pendimethalin in field experiments and commodities of various agricultural crops is available in literature, but unfortunately, information on the persistence and residues of this herbicide in produces of pulse crops is lacking. Therefore, this study was undertaken at to determine terminal residues and degradation pattern of pendimethalin in soil, greengram grain, and straw by following its pre-emergence application to greengram crop in field. The information is vital 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.

MATERIALS AND METHODS

Study design

The study was meticulously planned to determine the residues of pendimethalin in the soil, grain, and straw after its pre-emergence application in greengram crop. Field experiments were conducted for three years 2017-2019 at new research farm of Indian institute of Pulses Research, Kanpur, India. Soil physico-chemical characteristic of both of the IIPR farms are given 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 at the centre of Uttar Pradesh and falls in the agro climatic region of central Zone of the state with having tropical sub-humid climate. The region receives annual rainfall of 722 mm and mean annual maximum and minimum temperature of 33.0 and 20.0 °C, respectively. This agro climatic region is one of the most fertile tracts of Ganga and Jamuna basins and the soils of experimental site come under taxonomical class *Typic Usrtochrept* by containing sandy loam texture. Treatments comprised of pendimethalin 1000 g/ha, weedy check and weed free. The experiment was conducted under randomized block design with 3 replications. Greengram variety *'Samrat'* was used for the study, which has crop duration of approximately 60-65 days. Greengram was sown during 20-22 July in all the three years. Plant to plant distance was maintained approximately 10 cm with a row spacing of 30 cm. DAP was applied 60 kg/ha at the time of seedbed preparation. Pendimethalin was applied as pre-emergence within 24 hours of sowing using spray carrier volume 100 L/ha. Irrigation was not required due to sufficient rainfall during crop growth period. Plant protection measures were followed as per recommendations and need.

Sampling

From experimental plots, initial soil samples were collected at the time of sowing, thereafter samples were collected periodically by starting from just after 2 hrs of spray and second one at 5th day and thereafter a regular interval of 10 days, *viz.* 2 hrs, 5, 15, 25, 35, 45 and 55 days of herbicide spray and processed immediately for herbicide recovery. For the determination of terminal residues, soil samples were also collected at harvest (65-70 days). Approximately 0.5 kg of soil samples at depth of 15 cm were collected randomly from 10 to 15 different locations of pendimethalin treated and untreated plots by using a soil auger. Pebbles and other unwanted materials were screened out manually. The bulk soil samples from each one of the experimental plot were air dried under shade, powdered, and passed through a 3-mm sieve.

To determine the herbicide residue in greengram plants, approximately 0.5 kg of representative greengram plant samples were also collected randomly from the treated and untreated/control plots at the time of harvest. Grains were separated out from the plants samples and the remaining plant portions were cut into small pieces and air-dried

Table 1. Physicochemical characteristics of the experimental soil

Soil characteristic	Field location			
	IIPR main farm	IIPR, New research farm	Experimental field no. B 14 a	Soil filled in pots
Chemical properties				
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/h)	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
Physical properties				
Farm	Type	Sand (%)	Silt (%)	Clay (%)
Main farm	Sandy loam	46.6	26.6	26.8
NRF	Sandy soil	55.5	24.5	20.0

under shad. Greengram grains and straw samples were then ground 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 pendimethalin technical (1.0 mg/20 g soil). Pots were filled with 1.0 kg of soil collected from main research farm possessing soil physicochemical properties as described in **Table 1**. From treated pots, 10 g of soil samples were taken periodically, starting from just after 2 hrs of mixing of the technical and then after a regular interval of 10 days (10^{th}, 20^{th}, 30^{th}, 40^{th}, 50^{th} and finally at 70^{th} day).

Extraction and cleanup

Soil samples were air-dried, ground and stored at room temperature, however not kept them for more than three days. An amount of 10 g of subsamples was processed for extraction. Extraction was performed by shaking the samples for one hour with a mixture of 25 ml distilled water and 75 ml of acidified methanol which was obtained by mixing of 99 ml of methanol and 1 ml HCl and filtered. The soil deposited on filter paper was rinsed twice with the same extractants and filtered. From the obtained filtrates 25 ml was mixed with 25 ml of 0.1 N HCl and 50 ml of chloroform and then homogenized. The content was transferred to a separating funnel (500 ml) and shacked for some time. After proper shacking, the separating funnel was kept undisturbed for some time for settling the layers. The lower dichloromethane layer was collected, combined and dried on anhydrous Na_2SO_4, and passed through activated charcoal to remove coloring impurities. The solvent was evaporated completely to dryness at 45 ^{0}C temperature by using a rotary vacuum evaporator. Finally residues were dissolved in 5 ml of methanol and then subjected to cleanup. Extraction for greengram grain and straw was done by one hour shaking the 5 g samples with a mixture of 5 ml distilled water and 20 ml acetonitrile after adding 4 g $MgSO_4$ and 1 g NaCl. These samples were cleaned on a glass column (10 × 2 cm i.d.) packed with celite (1 g) and activated charcoal (0.25 g) between a layer of 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 again passed through MERCK, LiChrolut*RP-18, 1000mg columns prior to HPLC analysis.

Instrumentation

For detection purposes, pendimethalin residues were analyzed with a Shimadzu HPLC coupled with a diode array detector (DAD) at λ_{max} of 240 and 254 nm. 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 0.5 mL/min were used to separate out the pendimethalin residues. A 20-µL aliquot of the samples and standard were injected into the column with a micro syringe.

Method efficiency

In order to maintain the quality of the analytical data, quality control (QC) and quality assurance (QA) procedures were adopted since from the begging of collecting the soil samples and up to the stages of extraction and analysis. The extraction procedure adopted for recovery of pendimethalin residues from the samples of soil, straw and seed of greengram was found relatively simple and accurate. Since very few peaks was observed in chromatograms therefore the cleanup procedure adopted for purification of extracts was also found perfect to remove interfering substituent (**Figure 1**). For recovery check, the spiked samples (greengram grains, straw, and soil) were fortified by externally adding of the known concentration of pendimethalin standard solutions to ensure the herbicide concentrations in the samples in range of 0.01 to 1.0 µg/g. Thereafter, the extraction and cleanup processes as described above were adopted for calculation % recovery of the herbicide from the fortified samples. Calibration curve was obtained by taking known concentrations of pendimethalin pure technical, *viz.* 0.01, 0.05, 0.5, 1.0, and 5.0 µg/mL which were prepared in methanol by diluting a stock solution of 1000 µg/mL prepared from the same standard (**Table 2**). For this purpose certified standard of pendimethalin (Accu Standard, USA) was used. The concentration of pendimethalin was determined by comparing the peak area of the samples and calibration curves of five levels of standards and the % recovery was calculated as per formula *i.e.* % 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 of the background noise] and the limit of quantification (LOQ) [estimated to be 10 times of the background noise] were found to be 0.001 and 0.01 µg/mL, respectively. Dissipation pattern in field and pots were determined by periodically taking soil samples and determining the residue levels. The value of degradation constant was determined by using the formula *i.e.* $C = C_0e^{-kt}$ Where: C – amount of pendimethalin recovered from soil at time t; C_0 – amount of pendimethalin recovered at t = 0 interval; k = degradation constant; t = time in days. Effective time (T_{eff}) *i.e.* the time period by which the concentrations of herbicide lies between 1000 g/ha (original concentration) to 750 g/ha in field was calculated by utilizing the same equation.

RESULTS AND DISCUSSION

Recoveries and detection limit

In order to ensure analysis credibility, certain analytical parameters, *viz*. accuracy, precision, linearity and limits of detection (LOD) and quantification (LOQ) were taken into consideration. The accuracy of the method in terms of extraction efficiency was determined by doing recovery tests of fortified samples of soil/greengram straw/ greengram seed at concentration levels of 0.5 and 1.0 µg/g. Linearity was determined by different known concentrations (0.01, 0.1, 1.0, 5.0, and 10.0 µg/mL) those prepared by diluting the stock solution of 1000 µg/mL (**Table 2**). The limit of quantification of pendimethalin in soil, greengram grain and straw was workout and found to be 0.5 µg/g along with a signal to noise ratio of 3:1. A good linear analytical calibration graphs was received by plotting peak areas on the y axis against concentrations*i.e.*10 to 0.01 µg/ mL of pendimethalin on the x axis and based on that a calibration equation was devised. At this concentration range, the correlation coefficient was found nearly to 0.95. On the instrumental conditions as explained under the head of materials and method section, the retention time of pendimethalin was found to be approximately 7.45 minutes. Pendimethalin recoveries from the fortified samples varied from 92–83%, 88–84%, and 84–85% respectively, for soil, greengram straw, and greengram grain, after their fortification with 0.05 and 1.0 µg/g of pendimethalin (**Table 3**). The recovery of pesticide from the fortified soil, greengram grain and straw samples were considered acceptable with these two fortified levels. Hence, these recovery rates of pendimethalin from various matrixes at different concentration levels were rated as satisfactory.

Periodical and terminal residues of pendimethalin

Field experiments, conducted to observe the residue level and persistence of pendimethalin applied to greengram crop in sandy clay loam soil of taxonomical class *Typic Usrtochrept*, at any point of time revealed residues far below then its prescribed maximum residue limit as set by WHO/ FAO (0.5 mg/ kg). The amount of herbicide residues extracted from the soil samples of the three years *i.e.* 2017-2019 at different sampling intervals is shown in **Table 4**. The residue level of the herbicide in soil of treated plots of greengram field as well as in pots, revealed a constant rate of dissipation since beginning to the end of the experiment. The average of the three years of residue level of pendimethalin in experimental field soil at different intervals was found as 0.088, 0.080, 0.075, 0.065, 0.056 and 0.048 mg/g of soil respectively at 2 hrs, 5^{th}, 15^{th}, 25^{th}, 35^{th} and 45^{th} days (**Table 4**), whereas, in pots it was observed as 0.85, 0.76, 0.68, 0.62, 0.58, 0.51, 0.44 and 0.32 mg/g of soil respectively at 2 hrs, 10^{th}, 20^{th}, 30^{th}, 40^{th}, 50^{th}, 60^{th} and 70^{th} day of herbicide applications (**Table 5**). Result clearly revealed that the initial deposits of pendimethalin when applied at the rate of 1000 g/ha goes down nearly to 50% within 45 days of application and further reached to below LOQ after 65 days of application or at harvest of greengram crop. The obtained results are in good agreement with findings of Sondhia (2012), Tandon (2015) where they reported below detectable limit of residues of this herbicide in maize cobs, maize plant and soil when applied at the rates of 1 and 2 kg/ha. Experiments separately kept in pots also revealed almost the same pattern of herbicide degradation. Initial concentration of pendimethalin in pot (applied 1 mg/20 g of soil) after 2 hours of pendimethalin application was measured as 0.85 mg/g of soil were reached down to the 0.32 mg/g of soil within a period of 70 days hence this shows >60% degradation of herbicide during this period. Though the degradation rate and pattern of herbicide in field and pots were showed almost similar trend however, in pots, it seems to persist for slight longer period and that may be described on the bases of different environmental

Table 2. Calibration of pendimethalin standard at concentration level of 0.01 to 10 µg/mL

Injected concentration of pendimethalin (µg/mL)	Av. Area (mabs)[a)]	Std. deviation
0.01	16108	±1815.21
0.1	89383	±5449.28
1	212758	±10416.49
5	925710	±12739.27
10	3883000	±13941.59

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

Matrix	Fortification (µg/g)	Amount recovered (µg/g)	Recovery (%)
Soil	0.50	0.46±0.011	92
	1.00	0.83±0.015	83
Greengram straw	0.50	0.44±0.010	88
	1.00	0.84±0.013	84
Greengram seed	0.50	0.42±0.011	84
	1.00	0.85±0.017	85

conditions of pot and field. Since the pots were not exposed much to severe environmental conditions and the soil field in pots also found to retain different Physico-chemical soil properties (**Table 1**) moreover, the herbicide concentration in pots (1mg/20 g of soil) was much higher than the applied concentration (1000 g/ha) of field experiment. At the time of harvest, the grain and straw samples of greengram were found free from any kind of the herbicide residues. However, Sondhia (2012) reported a very low level of pendimethalin residues, *viz*. 0.025, 0.015, <0.001 µg/g and 0.015 to <0.001 µg/g in chickpea grain and straw after application of herbicide to the crop at 750, 350 and 185 g/ha, respectively. In case of field pea also a very low level of pendimethalin residues *i.e.* 0.004-BDL µg/g and 0.007- 0.001 µg/g, in grains of mature pea, and straw, respectively, was also reported by Sondhia (2013a) at 750-185 g/ha treatments. Since both of the crop are of winter season crop hence grown during winters where comparatively water stress conditions prevailed which may be the cause of getting minute pendimethalin residues in grains and plant parts however in contrary to that greengram crop under this trial was grown during full rainy season where frequent heavy rains along with enhanced microbial activities caused a faster removal of herbicide thereby no residue was detected in greengram grain and plant parts.

Persistence and dissipation pattern

The persistence or dissipation of an herbicide is mainly controlled by environmental conditions *viz.*, climate, soil physicochemical properties and microbial activities in the soil *vis a vis* the crop management practices Maria and Andrzej (2012) Kaur and Bhullar (2017). In present experiments, the degradation of pendimethalin, under mentioned soil conditions was found to operate as per first order kinetic equation, *viz.* [$dC_0/dt=K(C-C_0)$]. Disappearance trends of initial deposits of pendimethalin residues on soil surfaces, dissipation coefficients (K), half-life

Table 4. Periodical and terminal residues of pendimethalin in greengram soil, grains, and straw at different times

Sampling at time	Residue level of pendimethalin herbicides (mg/g) at λ max 254									
	Soil (NRF farm)			Average of 3 years	Straw (NRF farm)			Grain (NRF farm)		
	2017	2018	2019		2017	2018	2019	2017	2018	2019
2 hrs	0.081	0.091	0.091	0.088	-	-	-	-	-	-
5 days	0.073	0.088	0.080	0.080	-	-	-	-	-	-
15	0.069	0.079	0.077	0.075	-	-	-	-	-	-
25	0.061	0.065	0.069	0.065	-	-	-	-	-	-
35	0.051	0.057	0.059	0.056	-	-	-	-	-	-
45	0.041	0.053	0.051	0.048	-	-	-	-	-	-
55 (terminal residue)	<LOQ	<LOQ	<LOQ		<LOQ	<LOQ	<LOQ	ND	ND	ND

(ND) not detected

Table 5. Dissipation pattern, persistence and effective time in field and pots experiments

Sampling (at DAS)	Decay pattern of pendimethalin in field (1000 g/ha)					Decay pattern of pendimethalin in pot (1 mg/20 g of soil)				
	Dissipation pattern					Dissipation pattern				
	Residue Level (field) (mg/g soil)	% dissipation	rate constant (K)	$T_{1/2}$ (days)	Effective time (T_{eff}.) & persistence (90%deg.)	Residue Level (Pot) (mg/g soil)	% dissipation	rate constant (K)	$T_{1/2}$ (days)	Effective time (T_{eff}.) & persistence (90%decay)
2 hrs	$8.8x10^{-2}$	0.00	0.00	0.00	Effective time of	$8.5X10^{-1}$	0.00	Average K=	Average	Effective time of
					herbicide calculated			$1.11x10^{-2}$	=62	herbicide calculated
5th	$8.0x10^{-2}$	10.0	$1.90x10^{-2}$	36	on the bases of	-	-	-	-	on the bases of
10th	-				concentrations.	$7.6x10^{-1}$	11.00	$1.12x10^{-2}$	62	concentrations.
15th	$7.5x10^{-2}$	15.0	$1.06x10^{-2}$	65	between 1000-750			-		between 1000-750
20th	-	-	-	-	g/ha by taking	$6.8x10^{-1}$	20.00	$1.12x10^{-2}$	62	g/ha by taking
25th	$6.5x10^{-2}$	26.0	$1.21x10^{-2}$	57	average K-1.36x10-	-	-	-	-	average K-1.11x10-
30th	-	-	-	-	2 is=21days &	$6.2x10^{-1}$	27.00	$1.05x10^{-2}$	66	2 is= 26 d &
35th	$5.6x10^{-2}$	36.0	$1.29x10^{-2}$	54	Persistence (90%	-	-	-	-	Persistence (90%
40th	-	-	-	-	decay) =169days	$5.8x10^{-1}$	32.00	$9.55x10^{-3}$	72	decay) =209 days
45th	$4.8x10^{-2}$	45.0	$1.34x10^{-2}$	52		-	-	-	-	
50th	-	-	Average k	Average		$5.1x10^{-1}$	40.00	$1.02x10^{-2}$	63	
			$1.36x10^{-2}$	= 52 days						
60th	-	-	-	-		$4.4x10^{-1}$	48.00	$1.09x10^{-2}$	63	
70th	-	-	-	-		$3.2x10^{-1}$	62.00	$1.39x10^{-2}$	50	

($T_{1/2}$), effective time (T_{eff}), and persistence (90% degradation) of field and pot experiments are given in **Table 5** and expressed *via* the logarithmic plots of herbicides residue *vs* time represented in **Figure 1** and **2**. The half-lives of pendimethalin as calculated by using first order kinetic equation were found to be of 52 (average K=1.36x10^{-2}) and 62 (average K=1.11x10^{-2}) days, respectively, for field and pot experiments. Since the field experiments were conducted at new research farm (NRF) of the institute where soil differs little in its physico-chemical properties by having comparatively lesser clay and organic matter content, more sand and silt particles and high pH (nearly 8.5) as compared to the soil packed in pots (**Table 1**) taken from main research farm, therefore, comparatively 10 days lowered half-life of the herbicide is received in field experiments. The combined effect of soil physico-chemical properties, *viz.* high organic carbon and temperature on its half-life was also reported by Raj *et al.* (1999). Since, application rate of the herbicide in soil also linked to contribute toward longer half life and persistence therefore; this may also be one of the causes of receiving longer half-life in pot experiment as pots contained comparatively more concentration and also not exposed much to severe environmental conditions. However, the half-lives of this herbicide approximately between 50-60 days as received by us in our experiments are in close agreement with previous findings of other workers. A maximum half life period of 53.8 days or very near to that for pendimethalin was not only reported by Tandon (2008) but also reported by Tsiropolos and Miliadis (1998), Nicholas *et al.* (1998), Kalpana *et al.* (1999), Raj and Chhonkar (2000) and Rathod *et al.* (2010). Though, dinitroanilines are reported to have short life in soil, even though pendimethalin can persist up to 50 weeks as reported by Wen-Ching Chen *et al.* (2018), Marin *et al.* (2019), Bharti *et al.* (2020). This, 50 week persistence period is enough to exert toxic effects on the succeeding crops Smith *et al.* (1995).

In our experiments, we calculated 90% degradation in the herbicide within 169 and 206 days in field and pot experiments, respectively. The persistence of pendimethalin in soil was also found concentration dependent *i.e.* the doses used for weed control therefore Neelam *et al.* (2014) reported a persistent period of 90 days at dose 0.75 kg/ha and 120 days at doses 1.50 and 3.00 kg/ha. In this respect, Sinha *et al.* (1996) also reported almost similar results. However, Yadav *et al.* (1995) reported a persistence period of 200 days of this herbicide in a sandy loam soil which is broadly resembled to our farm soil at application rates of 1 to 4 kg/ha that also caused phyto-toxicity to the succeeding sorghum

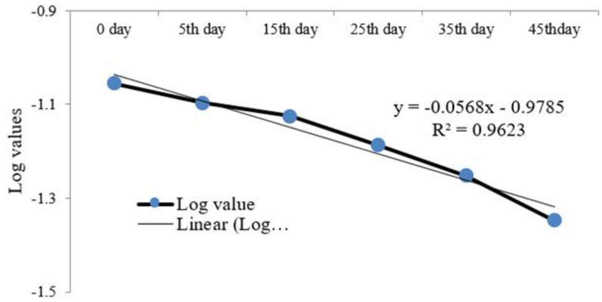

Figure 1. Degradation pattern of pendimethalin residues in the soil in field conditions

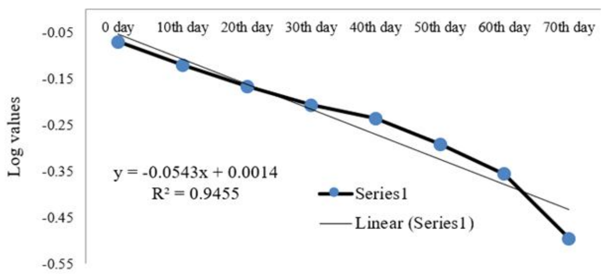

Figure 2. Degradation pattern of pendimethalin residues in the soil in pots

crop at higher dose. The effective period (T_{eff}.) of the herbicide, for weed control points of view was workout by using first order kinetic equation and by utilizing rate constant (K) values *i.e.*1.36x10^{-2} and 1.11x10^{-2} for field and pot experiments, respectively. The time period by which the concentrations of herbicide lies between 1000 g/ha (original concentration) to 750 g/ha in field was considered as most effective period for weed control point of views. According to this, as per our experimental conditions the herbicide assume effective for 21 days in field whereas in pots it was found nearly to 26 days. The present result suggest that once spray, the herbicide can only provide effective protection to crop against weed up to a maximum period of 20-25 days in our soil *i.e.* sandy clay loam soil of taxonomical class *Typic Usrtochrept* and may differ slightly is soils of having different soil properties and environment. Finally, it can be concluded that soil with an alkaline pH and less adsorption capacity in totality may leads to less terminal pendimethalin residues. Since in our experiments at harvest, the soil of experiments was not only found to retain residues of the herbicide below detectable limit even after 45 days of application but seed and straw of the crop was also found free from residues, however, the maximum permissible residue limit in plant parts and seed as set by WHO/ FAO is 0.5 mg/kg for this herbicide. It indicates that the use of pendimethalin in greengram crop could be considered safe.

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