Persistence of Pendimethalin in Southern Guinea Savanna, Ogbomoso, Nigeria

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ABSTRACT

Pendimethalin is experimented for persistence using Spectronic 2ID for residue analysis in Ogbomoso, Southern Guinea Savanna soil. Pendimethalin (1.0, 1.5, 2.0 l/ha), hoe weeded and Weedy Check (WC) were the applied treatments.Soil samples were taken for herbicide residue analysis to determine Disappearance Time for 50% (DT50) of the herbicide. The lowest rate, 1.0 l/ha disappeared faster than 1.5l/ha. Up to 75.2 days after application, 75% of the herbicide at the recommended rate of 2.0l/ha had disappeared. The DT_{50} were 48.3, 57.3 and 37.9 days for 1.0, 1.5 and 2.0 l/ha respectively. There was inadequacy in weed control ability of Pendimethalin due to the loss in quantity of the herbicide from the soil in this zone. Thus, before eight weeks of application more than half of the applied herbicide had disappeared leading to reduced weed control. However, Pendimethalin was found to be moderately persistent in the zone. This implied that the problem of choice of follow-crop does not arise and the compartments of the environment would be free from pendimethalin residues.
Keywords: *Disappearance time, Pendimethalin, Herbicide Persistence, Spectronic 2ID.*

INTRODUCTION

Experience has shown that the growing concern about agrochemical toxicity and residues in the environment appeared to be diverting attention from a chemical barrier needed in the soil to give sufficient herbicide concentration that can inhibit weed growth for roughly three months. A lot of factors determine the fate of any pesticide in the environment including soil physicochemical properties, rainfall, temperature, soil microbes, pesticide physicochemical properties etc. The bioavailability of most herbicides for microbial biodegradation is limited by the sorption to organic matter or clay minerals (Alexander 1994; Skow and Johnson 1997).

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Adsorption of pesticides to soil particles is beneficial as it reduces their leaching potential to groundwater, however, it might limit microbial degradation by limiting its bioavailability. While the adsorption of pesticides on to soil particles reduce their leaching potential to ground water and simultaneously limits their bioavailability to microorganism, degradation effects the concentration of pesticides residues in soils, thereby controlling their persistence in soil (Vischetti *et al.*, 2010). All these parameters were useful to evaluate pesticide persistence and mobility through the soil profile and to improve pesticide fate models that either provide predicted environmental concentrations or simulate environmental fate of pesticides (Vischetti *et al.*, 2010).

According to the European Commission (2003), the DT50 for Pendimethalin ((N-(1-ethylpropyl)-2, 6-dinitro-3, 4-xylidene) ranged as follows: Germany 27-102, France 82-141, and in South Africa 57-102 days. There is no universally accepted classification of pesticide environmental persistence. However, Roberts (1996) used a classification based on the mean half-life of the pesticide in the soil: I) Impersistent [or "non-persistent"], $DT_{50} < 5$ days; 2) slightly persistent, DT50 = 5-21 days; 3) moderately persistent, DT_{50}) = 22-60 days; and 4) Very persistent, $DT_{50} > 60$ days. Any estimate of field dissipation half-life or comparable index of persistence is dependent on a variety of factors (Roberts,1996). For example, DT_{50} values tend to be shorter in warm, moist climates compared to cooler, drier soils.

Alkaline soils tend to prolong persistence for certain herbicide classes, notably sulfonylureas and triazines. Thus, although a single value may be reported for DT_{50}, for an herbicide, it usually represents a range, often very wide. Efforts to reduce the rates of herbicide application are often associated with reduced efficacy (Ayeni and Zanin, 1979; Muyonga, Defelice and Sims, 1996) and therefore, added economic risk, in terms of repeated applications, to the farmer. Soil type effects on persistence per se have been shown to better be compared in field experiments due to the complicating influences of climate, especially rainfall and temperature (Sheets, 1970). It is therefore desirable to establish the persistence of a given herbicide within similar edaphic and climatic regions where the information is intended to be used.

In Nigeria, Ayeni (1991) observes that many a time, the herbicides are not within the reach of the farmers who are also both technically deficient to apply them correctly and economically poor to afford the high prices that the herbicides command. In addition, there is limited information on the safety of the chemicals in the Nigerian environment, as the only information available as regards these chemicals are reports from other parts of the world. Most degradation studies were conducted in the laboratories and results were difficult for field interpretation. Thus, there is the need for data which can be related to agro-ecosystems to which pesticides are applied (Greenhalg and Dreschler, 1982).

The objective of this study, therefore, is to trace the disappearance of Pendimethalin in Ogbomoso, Southern Guinea Savanna zone of Nigeria and to relate the persistence to the effectiveness of weed control in treated fields.

ISSN: 2141-2731

MATERIALS AND METHOD

The experiment was conducted at Ladoke Akintola University of Technology, Ogbomoso, Teaching and Research Farm and the Ogbomoso farm settlement for two seasons. Both sites are located at Ogbomoso in Oyo State, Nigeria.

Land preparation, experimental design and treatments application

The site in each of the two locations was disc ploughed twice and manually leveled after pegging into plots with measuring tape. The experiment was laid out in a completely randomized block design (CRBD) with five treatments in a block and replicated thrice. Each block contained 5 beds of 5m by 5m, and the block and bed were 2m apart. There were three levels of Pendimethalin 2.0l/ha, 1.5l/ha, and 1.0l/ha. Two controls of hand weeding alone and zero weed control (weedy check) were included.

Weed assessment

Weeds on the plots were assessed using 0.25m by 0.25m quadrats located at two spots per plot to take weed density three weeks after spraying and weed biomass, fresh weight of harvestable weeds eight weeks after spraying. The weeds were oven-dried at 80^{o}C in JP SELECTA, S.a. CE V230 Cod: 2000209 Serial number 0446955 at 80^{o}C to constant weight and weighed for dry matter evaluation using Gibertini TM 1600 Max.1600, d = 0.01 Top Loading balance.

Assessment of herbicide persistence in treated field plots

The herbicides residues were estimated by extraction from the soil. Soil samples were taken into polyethylene bags eight times, with the first within 24 hours of herbicides application. Two other samples were taken at weekly intervals while the remaining five were taken at two weekly intervals (Akinyemiju, Ogunyemi and Ojo, 1986). Three samples per plot, mixed together to form a composite sample were taken to a depth of 15cm using soil auger. The samples were taken to the laboratory within 48hours of sampling, for Spectronic 2ID analysis of the residue.

Extraction of Herbicide Residues

Soil sample (5g) was weighed using a Metler top loading balance and 25ml of ethyl acetate was added in the presence of anhydrous sodium sulphate (10g) and sodium chloride (10g). They were homogenized on shaker at a high speed for 3 minutes. The homogenate was filtered through a Whatman No. 1 filter paper. The filtrate was left to pass through activated charcoal, (i.e. the activated charcoal was put on filter paper when the solution was then poured). The clear filtrate was then read on the Spectronic 21D at 420nm wavelength. The standards were prepared using Pendimethalin 500EC at 0.5ppm, 1.0ppm, 1.5ppm, 2.0ppm. The standard curve is plotted to obtain the slope.

ISSN: 2141-2731

Calculation

Absorbance x Slope x Dilution Factor

Slope for Pendimethalin = 0.120

(AOAC 2005; Miller, Rosenberg, Siltamen and Wartiovarra, 1981)

Statistical Analysis

Data from persistence soil analysis were subjected to regression analysis and regression plots obtained.

RESULTS AND DISCUSSION

The meteorological data during the two growing seasons were presented in Table 1. Figures 1a-f and 2a-f showed the disappearance of Pendimethalin with time. There was no apparent initial lag phase during which no appreciable losses of the herbicides occur. In general, there was a decrease in the concentrations of the herbicide residues in the soil from the day of application irrespective of the rate. There was non-linear initial disappearance of Pendimethalin except at LAUTECH Farm in Year A and Year B (Table 3) where DT_{10} of Pendimethalin ranged from 3.5 to 12 days (less than 2 weeks) after application. Between 35.3 to 61.2 days (about 5-9weeks) after application, 50% of Pendimethalin had disappeared. On the average, 90% of Pendimethalin had disappeared by about 94 days after application (Table 3). The rate of disappearance of Pendimethalin was observed to be decreasing with decreased concentration of residue in the soil. Thus, between 3.58 - 6.2 mg/kg Pendimethalin disappeared within 0 - 28 days. Between 85 - 98 days after application, less than 1.6mg/kg of pendimethalin disappeared. The lowest rate of Pendimethalin applied, 1.0 l/ha, had almost disappeared completely by the thirteenth week of the experiment (Table 4).

Averagely, about 50% of Pendimethalin had disappeared at about eight weeks after application. The DT_{90} (disappearance time for 90% of the initial residue) for the herbicide rates were shown in Table 3. By the 8th week of herbicide application, 2.0l/ha Pendimethalin gave 31.45% weed control at LAUTECH farm in Year A. The percentage weed control of less than 45% was recorded for the herbicide in Year B at Ogbomoso Farm settlement. The weed control was better in Year B and during this time 56-70% weed control was achieved in both locations.

The initial weed control was high at 3 weeks after spraying (WAS) as shown in Table 5 in which the percentage weed control were calculated based on weed population, 3 weeks after planting. The results on the table 2 indicate great difference in weed control ability of the herbicide between 3 and 8 WAS. At the 3 WAS when weed density was estimated, more than 75% of the Pendimethalin remained in the soil while more than 50% of the herbicide has disappeared before the eighth week of the experiment during which the weed biomass was taken. The percentage weed control (69%) at LAUTECH Farm was best in Year B for the herbicide by week eight. There was no apparent initial lag phase during which no appreciable losses of the herbicides occur (Akinyemiju, Ogunyemi and Ojo, 1986). The disappearance of pendimethalin commenced immediately after spraying.

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The loss in phytotoxicity and inability of Pendimethalin at the recommended rate of 2.0l/ha to control weeds adequately beyond eight weeks after application was due to the low level of the herbicide residue in the soil at this period. The remaining concentration in the soil from this period was not enough to appreciably control the weeds hence the degree of weediness observed after eighth week of spraying. This suggested that the herbicide might have lost some of its efficacy before 56 Days After Application (DAP) due to factors such as degradation, leaching, runoff, volatilization and soil (and related meteorological) characteristics.

Dissipation of pendimethalin proceeds more rapidly under flooded, anaerobic conditions than cold or dry conditions (Stranberg and Scott-Fordsmand, 2004; Kulshrestha and Singh, 1992). Zimdahl, Catizone and Butcher (1984); Zimdahl, Cranmer and Stroup (1994) suggest that soil type may have less influence than temperature and soil moisture. This was why in the second part of this study, pendimethalin dissipation in two soils under three moisture levels and three mixtures of pesticides was performed. Results show that increasing the moisture level in soil from 30% to 90% of field capacity could result in an almost fourfold increase of degradation rate of pendimethalin alone in sandy loam and clay loam (Maria and Andrzej, 2012).

The meteorological data during the Year A and Year B cropping seasons revealed higher temperature, evapo-transpiration, sunshine and rainfall in Year A than Year B. There are many reports of herbicides and other pesticides dissipating more rapidly in tropical than in temperate climates (Helling, 1997; Racke *et al.*, 1997; Laabs, Amelung, Pinto and Zech 2002). This is more likely to be related to higher mean soil temperature in tropical and subtropical areas. Pendimethalin with vapour pressure of 1.94×10^{-3} Pa at $25^{o}C$ are likely to have vaporized more during Year A than Year B.

There are some reports on the degradation of pendimethalin by microorganisms comprising *Azotobacter chroococcum*, *A. vinelandii* and *Bacillus circulans* (Saha, Chowdhury and Chaudhuri, 1991; Singh and Kulashrestha, 1991; Kole *et al*., 1994; Megadi, Hoskeri, Mulla and Ninnekar, 2010). With low water solubility, moderate to high vapour pressure, strong adsorption to soil, and high octanol–water partition coefficients of pendimethalin, it would be expected that the movement of this herbicide in surface runoff and leaching be low except where soil erosion results in sediment transport of the adsorbed herbicide (Stranberg and Scott-Fordsmand, 2004; Chopra, Kumari and Sharma, 2010).

Health Canada (2004) reported that leaching may occur under conditions of excessive rainfall or irrigation, Pendimethalin could have been leached seriously during Year A heavy rain. Such leached chemical no longer contribute to weed control and has lessen persistence in the zone relevant to crop production. In the Southern Guinea Savanna zone, the recommended rate of 2.0l/ha disappeared faster than the other two rates but still gave the best weed control. The 1.0 l/ha treatment disappeared faster than 1.5 l/ha and gave the least percentage weed control of 37.6%. The DT_{50} for Pendimethalin in this zone, irrespective of the rate of application ranged between 37.9 and 57.3 days. By the classification of DT_{50} put forward by Roberts (1996), Pendimethalin was moderately persistent (22-60days) in this zone. However, US Environmental Protection Agency has

ISSN: 2141-2731

classified this herbicide as persistent-bio-accumulative toxics (Roca *et al*., 2009).

Table 1: Monthly weather data of Nigerian Meteorological Agency, Ilorin Airport Meteorological data during the experiment (Year A and Year B)

Date (months)	Temp(°C) Max	Min	Mean T(°C)	Relative Humidity (%)	Sunshine (Hrs)	Rainfall (mm)	No of Rainy days	Pitch Evaporimater
Year A								
July	29.8	21.8	25.8	87	5.4	318.6	18	2.6
August	28.9	21.7	25.3	89	4.8	226.3	19	2.8
September	30.1	21.7	25.9	88	4.5	270.3	21	2.3
October	32.3	21.8	27.1	83	7.5	224.5	11	3.4
November	34.9	21.3	28.1	75	8.1	4.8	1	7.2
Year B								
July	30.0	21.8	25.9	90	4.7	313.4	16	2,7
August	27.3	22.0	24.7	90	3.8	209.1	13	2.4
September	30.5	21.9	26.2	86	2.3	185.7	19	2.3
October	31.4	22.0	26.7	85	5.3	122.8	13	2.7
November	33.4	20.2	26.8	67	7.5	4.4	2	3.7
December	33.2	19.2	26.2	-	-	0	nil	-

Source: Experimentation, 2015 - 2016

Table 2: Effect of Pendimethalin on weed density 21 days after spraying, and weed biomass 56 days after spraying.

Application rate (l/ha)	Weed density (% of control)	Weed biomass (% of control)
LTRF Year A		
2.0	61.3	31.5
1.5	59.3	28.9
1.0	48.6	15.1
HW	22.4	37.5
OFS Year A		
2.0	74.3	42.6
1.5	82.0	40.8
1.0	63.4	25.7
HW	8.8	41.4
LTRF Year B		
2.0	77.2	69.6
1.5	59.3	67.6
1.0	59.5	62.1
HW	-	58.7
OFS Year B		
2.0	78.2	61.8
1.5	64.3	40.4
1.0	56.6	47.6
HW	6.0	52.4

LTRF = LAUTECH Farm; OFS = Ogbomoso Farm Settlement

ISSN: 2141-2731

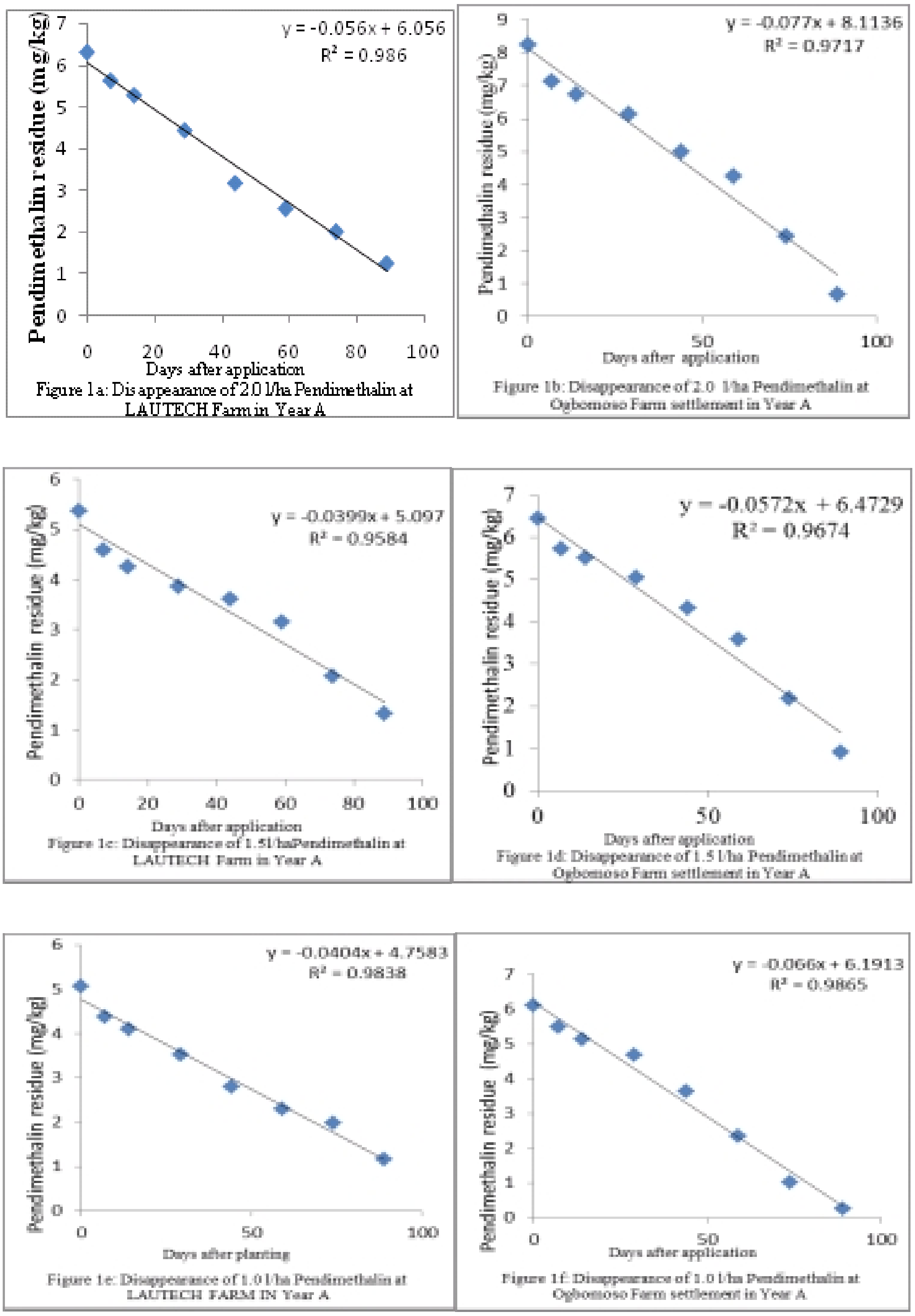

Figure 1: Regression plots of the disappearance of pendimethalin with time in Year A

ISSN: 2141-2731

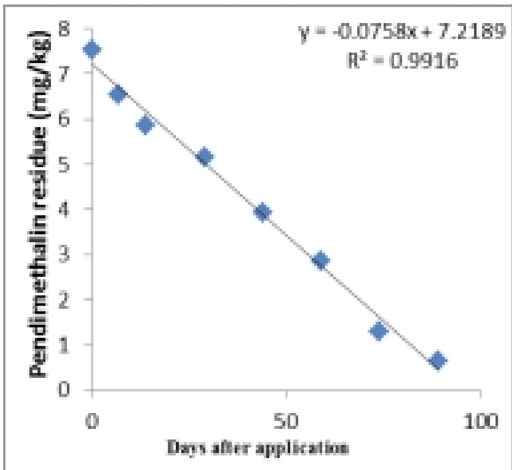

Figure 2a: Disappearance of 2.0 l/ha Pendimethalin at LAUTECH Farm in Year B

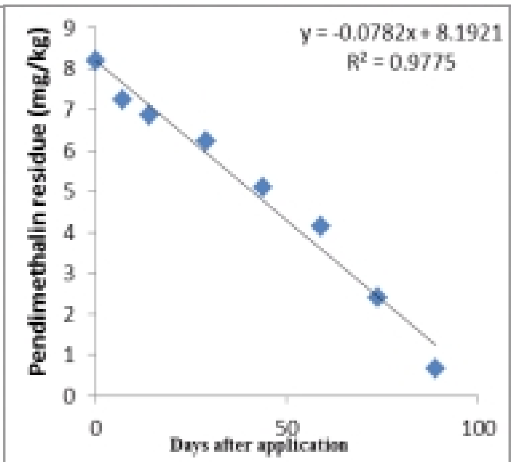

Figure 2b: Disappearance of 2.0 l/ha Pendimethalin at Ogbomoso Farm settlement in Year B

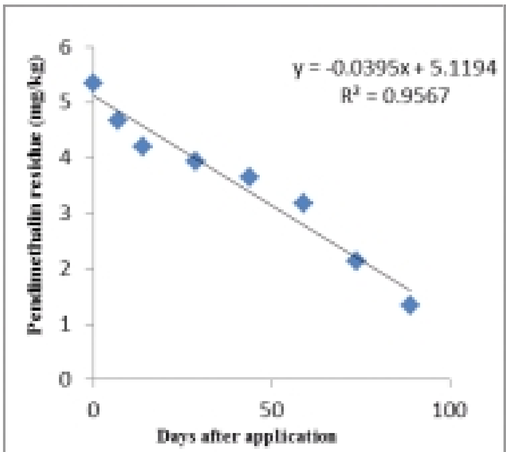

Figure 2c: Disappearance of 1.5 l/ha Pendimethalin at LAUTECH Farm in Year B

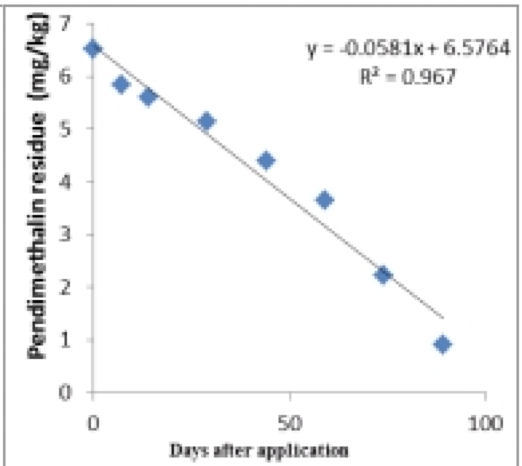

Figure 2d: Disappearance of 1.5 l/ha Pendimethalin at Ogbomoso Farm settlement in Year B

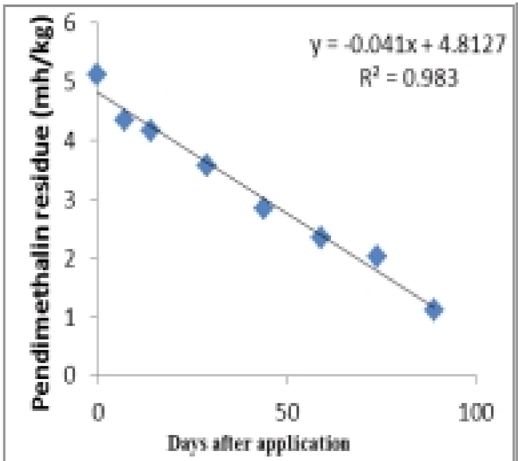

Figure 2e: Disappearance of 1.0 l/ha Pendimethalin at LAUTECH Farm in Year B

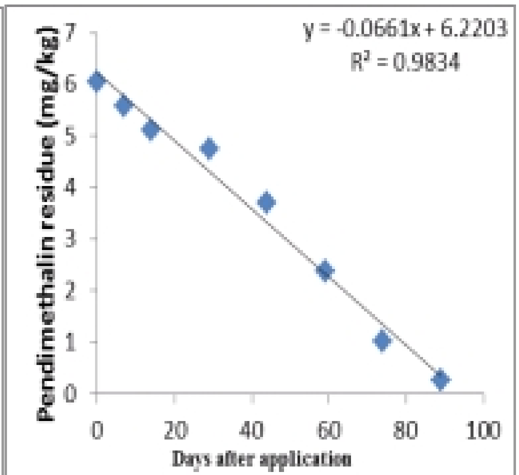

Figure 2f: Disappearance of 1.0 l/ha Pendimethalin at Ogbomoso Farm settlement in Year B

Figure 2: Regression plots of the disappearance of pendimethalin with time in Year B

ISSN: 2141-2731

Table 3: Characteristics of Pendimethalin in Southern Guinea Savanna zone of Nigeria as derived from the work.

Rate mg/kg	2.0	1.5	1.0
Mean DT_{50} (days)	37.9	57.3	48.3
Mean % Wd control 56 DAS	51.4	44.4	37.6
Mean % Res. 89 DAS	8.3	19.4	13.4
Disappearance rate mg/kg:			
DAS:			
0-28	5.6	4.8	4.2
29-56	3.4	4.0	2.5
57-84	1.3	1.6	0.9
85-98	0.4	0.9	0.2

Key: Wd = Weed, DAS = Day after spraying, Res. – Residue.
Source: Experimentation (2015 - 2016).

CONCLUSION

This experiment was carried out to ascertain the Persistence of Pendimethalin in Southern Guinea Savanna, Ogbomoso, Nigeria. Findings show thatbefore eight weeks of application more than half of the applied herbicide had disappeared leading to reduced weed control. However, Pendimethalin was found to be moderately persistent in the zone. This implied that the problem of choice of follow-crop does not arise and the compartments of the environment would be free from pendimethalin residues. Findings further show that the rates of pendimethalin applied were moderately persistent in the southern guinea savannah of Nigeria thus putting to rest the fear of environmental pollution. However, the rates were not very effective in weed control. Therefore, the rate of disappearance decreased with decreasing residue concentration in the soil. Toxicity of pendimethalin to follow-crop and the environment would have been drastically reduced prior to three months after application.

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