Persistence of Atrazine in a Humid Tropical Soil in the Early and Late Cropping Seasons[1]

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ABSTRACT

The persistence of atrazine (6-chloro-N-ethyl-N'-(1-methlyl ethyl)-1, 3, 5-triazine-2, 4-diamine) was monitored using a tomato (*Lycopersicon esculentum* Mill.) bioassay in both the early and late cropping seasons of a humid tropical environment. A single soil application of atrazine at 3.0 kg and 6.0 kg a.i./ha in the early season, and 1.5 kg, 3.0 kg and 6.0 kg a.i./ha in the late season was carried out in the field at the beginning of each planting season. The amount of atrazine residue in the surface soil after application was monitored using three-week-old tomato seedlings. Results showed that atrazine applied at the field rate of 3.0 kg a.i./ha was no longer present at a phytotoxic level at 70 days after application, irrespective of the season. Doubling the rate of application to 6.0 kg a.i./ha did not increase the persistence beyond the 70 days after application in both seasons. The best fit multiple regression equations showed that an assessment of the number of plants showing visual symptoms of atrazine injury, the extent of leaf area showing necrotic lesions and the shoot dry weight of the tomato seedlings can be used jointly or individually as indices of phytotoxicity in monitoring atrazine residue in this tropical soil.

COMPENDIO

La persistencia de atrazina (6-cloro-N-etil-N'-(1-metiletil)-1, 3, 5-triazina-2, 4-diamina) fue determinada mediante un bioensayo en tomate (*Lycopersicon esculentum* Mill.), durante las temporadas de cosecha precoz y tardía, en suelo o medio húmedo tropical. Se aplicó, en el suelo, una dosis de atrazina de 3.0 kg y 6.0 kg i.a./ha en la temporada precoz, y de 1.5 kg i.a./ha, 3.0 kg i.a./ha, y 6.0 kg i.a./ha en la tardía, al inicio de la plantación. Se midió la cantidad de residuos de atrazina, en la superficie del suelo después de la aplicación, en plántulas de tomate de tres semanas. Los resultados demostraron la ausencia de fitotoxicidad, en una proporción de 3.0 kg i.a./ha de atrazina, setenta días después de la aplicación, en cualquier temporada. La tasa duplicada no aumentó la persistencia en los setenta días siguientes, en ambas épocas. Las ecuaciones de regresión más adecuadas demostraron que la valoración, distinta o en conjunto, del número de plantas con síntomas visuales, de la extensión de lesiones necróticas sobre la superficie de las hojas, y del peso seco de las plántulas, puede utilizarse como índice de fitotoxicidad, para estimar los residuos de atrazina.

INTRODUCTION

The current increase in the use of atrazine in small to large scale maize farms in Nigeria has generated interest in the study of the persistence of atrazine in Nigerian soils (1, 6, 12). The persistence of atrazine in soils is important in knowing the duration of effective weed control and in deciding what crops will follow where atrazine has been used in a previous season.

The persistence of atrazine has been determined in the humid and sub-humid ecological zones in Nigeria (1, 6, 12). These studies were restricted to only one of the two seasons of the humid tropical region. The two cropping seasons are distinguished primarily on

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the basis of the amount and distribution of rainfall between January and December. It is expected that atrazine persistence in the two season will depend primarily on the amount and distribution of rainfall and its effect on the soil's physical and chemical properties.

Herbicide concentration in soils can be determined by chemical analyses or by bioassay (2). Recently, the persistence of atrazine in a Nigeria soil was determined using the spectrophotometric method (1).

However, this method is cumbersome and expensive, and may not correlate well with plant response. Chemical analyses in general only determine the amount of herbicide present in the soil, which may or may not be directly available to the crop. Bioassay techniques have been used extensively as a rapid, inexpensive method for the quantitative determination of herbicide residue in soil (2, 3, 5, 9). Bioassays, unlike chemical analyses, monitor the actual phytotoxic amounts of herbicide residue available to sensitive crops.

The objective of this study was to monitor the persistence of atrazine in a tropical rainforest soil both in the early and late cropping seasons using a tomato bioassay. It is expected that the bioassay will confirm results from a previous chemical analysis of atrazine residue and provide a simple and quick method of monitoring atrazine residue in the humid tropical field soil.

MATERIALS AND METHODS

The experiment was conducted at the University Teaching and Research Farm Obafemi Awolowo University, Ile-Ife in the early (April-July) and late (August-November) cropping seasons of 1983. The weather conditions at the farm (lat. 7° 28' N, long. 4° 33' E and altitude 244 masl) during the year the experiment was conducted are presented in Table 1, and are typical of the pattern in the tropical rain forest belt of the humid tropics. The experimental field had been in fallow for the previous fifteen years. Before the study was laid out the land was cleared, ploughed twice and harrowed once with a tractor-mounted disc plough or harrow. The soil was of a loamy-sand texture with an organic matter content of 2% C and pH 6.1. In the early season trial, the experiment was located on a 25 m x 11 m plot containing three replicates of 25 m x 3 m each, and with a 1 m strip separating each replicate. Each replicate was further divided into 3 plots of 25 m x 1 m each. Two rates of atrazine, 6.0 kg and 3.0 kg a.i./ha and a control (0.0 kg a.i./ha) were applied at random among the three plots of each replicate. The layout and design in the late season was similar to the previous one except for the inclusion of a new rate of 1.5 a.i./ha atrazine.

In each trial, the weighed atrazine was mixed with two liters of water and sprayed on the 25 m x 1 m strips using portable pressurized sprayers previously calibrated to deliver two liters of spray solution per 25 m^2 at a pressure of 2-3 kg/cm^2. The spraying was

Table 1. Weather data at the University Teaching and Research Farm Obafemi Awolowo University (January – December 1983).

Month	Temperature°C Mean (10.00 h)	Depth soil at 10 cm	Relative (10.00 h)	Humidity (%) (16.00 h)	Sunshine (h) mean	Total (mm)	Rainfall (rainy days)	Solar radiation (watts/m^2/d)
Jan	21.5	26.9	39.6	24.7	5.4	0	0.0	4 128
Feb.	24.15	31.9	65.4	34.4	6.4	2.6	1.0	4 576
March	26.6	30.3	60.6	27.3	4.8	0.5	1.0	4 036
April	26.9	29.1	77.1	48.6	6.3	108.8	7.0	3 867
May	26.1	28.6	80.9	63.1	5.6	158.7	12.0	2 559
June	24.1	26.9	86.4	73.1	3.6	198.1	17.0	3 990
July	23.1	27.0	87.0	74.0	4.5	169.9	13.0	--
Aug.	22.3	26.0	77.9	75.5	1.1	42.7	7.0	4 039
Sept.	23.6	26.5	86.0	70.6	3.3	174.0	19.0	3 560 1
Oct.	24.9	27.6	82.0	62.5	4.7	54.3	8.0	4 107 4
Nov.	25.6	28.8	74.0	49.0	6.8	0.0	0.0	4 592
Dec.	24.5	25.9	77.4	55.3	5.0	35.3	3.0	3 814

carried out on April 20, and September 9, 1983 for the early and late seasons respectively.

Soil samples were collected from a randomly selected 1 m x 1 m x 7.5 cm section of each 25 m x 1 m herbicide-treated strip, and from the control in the three replicates, for a total of nine samples in the early, and 12 samples in the late season trials, respectively, at each sampling date. Each soil sample was scooped with a hand trowel to a depth of 7.5 cm, thoroughly mixed and distributed equally into three wooden trays each measuring 45 cm x 35 cm x 7.5 cm. In both seasons the first soil sample was collected immediately after atrazine application, the next two samples were collected at weekly intervals, while subsequent samples were collected at two-weekly intervals.

Bioassay

Tomato (*L. esculentum* Mill.) seeds were first sown at a rate of 144 per wooden tray measuring 45 cm x 35 cm x 7.5 cm and filled with steam pasteurized greenhouse soil. Watering was carried out regularly every morning for three weeks, a period, determined by a preliminary test, to be sufficient to produce suitable tomato seedlings for the bioassay. Tomato seedlings were subsequently produced for each bioassay by seeding tomato, three weeks before a set of soil samples were collected. Seedlings used for each bioassay were selected among several for uniformity in vigour, height and number of leaves. Twenty tomato seedlings were then transplanted into each tray containing the treated soil sample, for a total of 60 seedlings distributed in three trays per soil sample.

Height, number of leaves, number of plants showing symptoms of atrazine injury and, percentage leaf area showing necrosis and "burning" effects were determined two weeks after each transplanting. The shoot dry weight was also taken at the same time after oven drying at 80°C for 48 hours. Subsequent sampling and transplanting were carried out until no visual symptoms of herbicide injury was observed on two consecutive sampling periods.

The experiment was a split-plot design with rates of atrazine as main plots and times after application as subplots. There were three replicates of each rate of atrazine and the control, and treatments were randomized within each block. The data collected were analysed statistically and means were compared using the least significant difference (LSD) test at the 5 per cent level of probability (11). Parameters that showed potential for use in monitoring the phytotoxicity of atrazine residue in the soil were further subjected to regression analysis and the best-fit regression models and curves for the data are presented.

RESULTS

The response of the most responsive *L. esculentum* Mill. parameters evaluated at the different times after atrazine application in the early and late seasons are presented in Figs. 1 and 2.

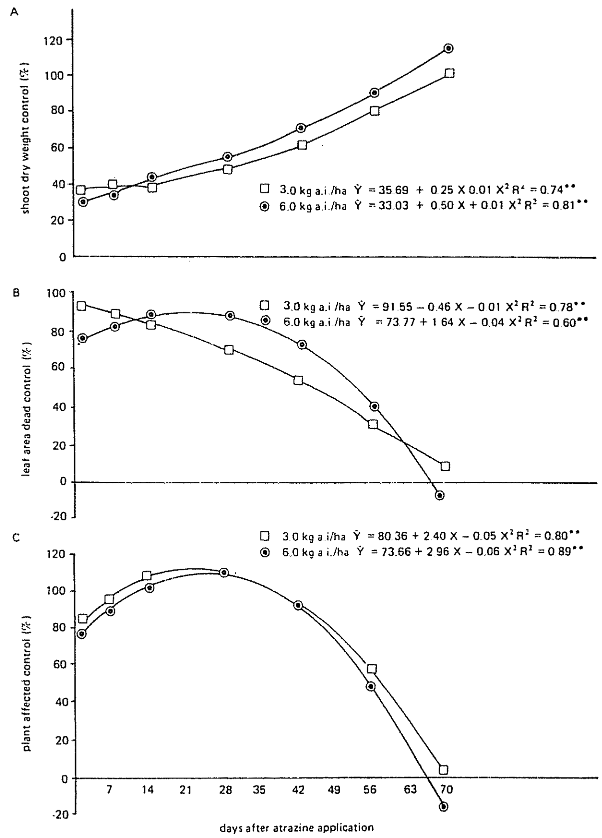

Fig. 1 Disappearance of atrazine following a pre-emergence application on a humid tropical soil in early season.

Fig. 1 shows the fitted curves from the best multiple regression equation of the two visually-assessed parameters, number of plants affected (NPA) and leaf area dead (LAD), and the shoot dry weights (SDW) on time after atrazine application in the early season. The number of plants showing visual symptoms and the leaf area showing necrotic lesions (dead), decreased generally from the highest (0 d) to the lowest (70 d) after application when plants on treated soil were not different from the untreated control. Similarly the shoot dry weight at both levels of application showed a progressive increase from time of application to day 70 when treatment effect had disappeared (Fig. 1). The unstandardized partial regression coefficients (b-values) and coefficient of determination (R^2) from the multiple regression equations using the three parameters NPA, LAD, and SDW in the early season is shown in Table 2. The contribution of the cubic equation is very small, and as such was discarded; variation in the response of the evaluated parameters is accounted for by the quadratic equation (Table 2).

Table 2. Unstandardized partial regression coefficients (b-values) and coefficient of determination (R^2) from multiple regression of time after atrazine application (X) on different tomato bioassay parameters in the early season.

Tomato bioassay parameter	Rates of atrazine (kg a.i./ha)	b–values	R^2
Number of plants injured	3.0	X −2.40	0.57**
		X^2 −0.05	0.80**
	6.0	X 2.96	0.54**
		X^2 −0.06	0.89**
Leaf area dead	3.0	X −0.46	0.76**
		X^2 −0.01	0.78**
	6.0	X 1.64	0.44**
		X^2 −0.04	0.60**
Shoot dry weight	3.0	X 0.25	0.72**
		X^2 0.01	0.74**
	6.0	X 0.50	0.80**
		X^2 0.01	0.81**

** = Significant at P = 0.01

Also the coefficients of determination in the quadratic equation for each parameter were very significant (at 1% level) and hence the choice of the quadratic to fit the response curves.

The fitted graphs from multiple regression equations of the parameters evaluated for the late season trial is shown in Fig. 2. The same parameters selected for the multiple regression equations in the early season were also used in the late season. In general, the parameters experienced the highest degree of phytotoxicity at the earlier days after application, but the phytotoxic effect of atrazine residue decreased with time until day 70 when treatment effect was no longer observed.

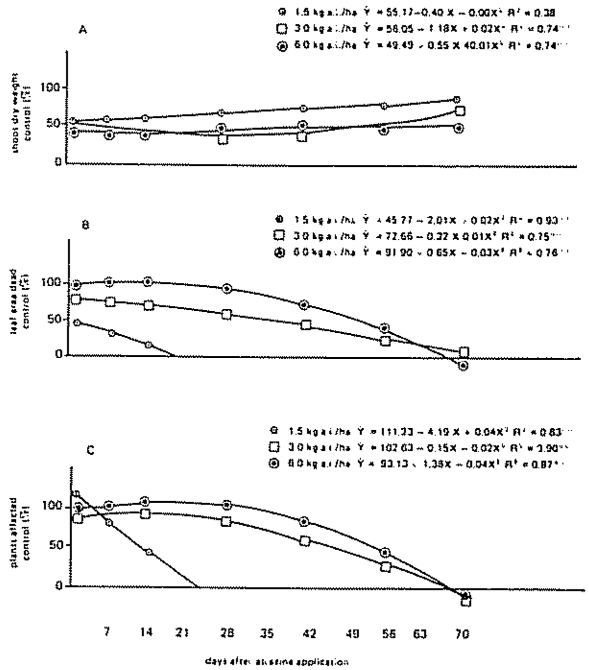

Fig. 2 Disappearance of atrazine following a pre-emergence application on a humid tropical soil in the late season.

There were differences in the response of the different rates of atrazine: the lowest rate, showing the least phytotoxic effect while the highest rate showed the most (Fig. 2). Table 3 shows the b-values and R^2 from the quadratic regression equations. Again, as observed in the equation obtained from the early season trial, most of the R^2 are significant at the 1 per cent level, and most of the observed responses can be explained by the quadratic equation (Table 3).

DISCUSSION

It could be inferred from the results presented that atrazine at field rates of 3.0 kg a.i./ha disappeared from the soil and was no longer present in sufficient quantities to be phytotoxic to *L. esculentum* Mill.

Table 3. Unstandardized partial regression coefficient (b-values) and coefficient of determination (R^2) from multiple regression of time after atrazine application (X) on different tomato bioassay parameters in the late season.

Tomato bioassay parameter	Rate of atrazine (kg a.i./ha)	b–values	R^2
Number of plants injured	1.5	X 4.19	0.70**
		X^2 0.04	0.83**
	3.0	X -0.15	0.85**
		X^2 –0.02	0.90**
	6.0	X 1.38	0.65**
		X^2 –0.04	0.87**
Leaf area dead	1.5	X –2.02	0.68**
		X^2 0.02	0.93**
	3.0	X –0.32	0.73**
		X^2 –0.01	0.75**
	6.0	X 0.65	0.65**
		X^2 –0.03	0.76**
Shoot dry weight	1.5	X 0.40	0.38**
		X^2 0.00	0.38NS
	3.0	X –1.8	0.40*
		X^2 0.02	0.74**
	6.0	X –0.55	0.60**
		X^2 0.01	0.74**

*, ** Significant at P = 0.05 and 0.01 respectively; NS = not significant

seedlings at 70 d after the initial application, irrespective of the season. Doubling the rate from 3.0 to 6.0 kg a.i./ha did not increase the persistence beyond the 70 d when most of the atrazine had disappeared.

In an earlier study Akinyemiju *et al.* (1) reported the short persistence of atrazine in a similar soil. Using a spectrophotometer they observed that only about 10 ppm of initial atrazine was detected in the soil at 70 d after an application of 3.0 kg. Work done at the International Institute of Tropical Agriculture (6) and by Utulu *et al.* (12) also showed that atrazine at the field rate of 3.0 kg a.i./ha persists for only eight weeks in two different ecological zones within Nigeria, and that doubling the rates did not increase its persistence. Thus the *L. esculentum* Mill. bioassay has confirmed the short persistence of atrazine, as reported earlier on this soil, and has shown that it could be used to monitor the actual phototoxic amount of atrazine residue in the soil. The short persistence of atrazine (70 d) in this tropical soil and environment is in contrast to those reported for temperate zone soils where a field rate of 3.0 kg a.i./ha atrazine is expected to give a full season's control of between 3 - 12 months (4, 7, 8). The short persistence in this humid tropical soil, in contrast to the longer persistence in the temperate zone soils, can be explained by the observation in Slack *et al.* (10) that a warm, moist climate promotes the disappearance of triazine herbicides from soil and that persistence is more prolonged in cold, dry climates.

In 1983 when this experiment was conducted, the distribution of rainfall in the two seasons was similar; the total amounts of rainfall (468.7 mm in the early and 305.3 mm in the late seasons) were different. In spite of the differences in the amount of rainfall, the disappearance of atrazine in both season was similar. In the late season there were differences in the disappearance of each rate of atrazine. The difference might be due to the lower amount of total rainfall which might have reduced ru.ı-off and leaching losses thereby allowing the different rates to be differentially degraded.

The graphs of the regression analyses showed that any of the three selected tomato bioassay parameters, NPA, LAD and SDW, could be used as a single index of phytotoxicity in monitoring atrazine in soils because each of them had a high and significant coefficient of determination. These parameters are fairly easy to determine and show relative sensitivity at different rates of atrazine.

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RESEÑA DE LIBROS

INTERNATIONAL RICE RESEARCH INSTITUTE. 1990. Phosphorus requirements for sustainable agriculture in Asia and Oceania. Manila, Filipinas, IIRI, 478 p.

Este volumen presenta los trabajos específicos y las recomendaciones de los grupos de trabajo de una conferencia promovida por el *International Rice Research Institute* (IRRI), las Naciones Unidas y diversas organizaciones técnicas.

Dichos trabajos resumen información muy actualizada sobre tres tópicos: a) el estado y el manejo del fósforo en los cultivos principales de Asia y Oceanía: arroz, leguminosas de grano y diversos cultivos perennes como café, té, cacao, palma aceitera y otros; b) el uso del fósforo y sus abonos en diferentes partes de la región; y c) los aspectos básicos del comportamiento del fósforo y los factores de los suelos de la región que influyen en él.

Se presenta una amplia discusión sobre las diferentes formas de fósforo que se pueden usar, con énfasis en aquellas de bajo costo, como las rocas fosfatadas y sus diferentes formas tratadas. También se examinan las interacciones entre el fósforo y otros elementos esenciales, respecto de las condiciones agrícolas de la región, en medios similares a los de Latinoamérica.

Este texto, como muchos otros editados por el IRRI, es una excelente adición para todas las bibliotecas de investigación y enseñanza de agricultura tropical, ya que en él se presenta información muy actualizada y acompañada por citas bibliográficas pertinentes.

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