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Degradation and residual effects of endosulfan on soil chemical properties and root- knot nematode *Meloidogyne incognita* populations in cocoa plantation in Ibadan, Nigeria

Aikpokpodion*[1] P.E , Lajide [2]L.,Ogunlade [1]M.O, Ipinmoroti [1]R.,Orisajo [1]S.,Iloyanomon C.I[1]. and Fademi O[1].

[1]Cocoa Research Institute of Nigeria P.M.B.5244, Ibadan, Nigeria; [2]Federal University of Technology, P.M.B. 704, Akure, Nigeria.
***Corresponding author**: paulaikpokpodion2@yahoo.com

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ABSTRACT

Objective: To determine the degradation of endosulfan in Ibadan soil and to evaluate the effect of the recommended rate (0.25% a.i) of the insecticide (endosulfan 35EC) on some soil chemical properties and plant parasitic nematode (*M. incognita*) population in a cocoa plantation.

Methodology and results: Soil samples were collected on monthly basis from one of the cocoa plantations of Cocoa research Institute of Nigeria for six months after the second application of the insecticide (endosulfan).Samples were analyzed chemically according to standard procedure; nematode population was determined according to Whitehead & Hemming (1965) and pesticide residue in soil was determined as described by Luisa *et al*. (2004). Result showed that application of endosulfan 35EC significantly increased the acidity, magnesium and iron content of the treated soil, reduced the concentration of calcium, potassium, and sodium in the treated soil. An average of 3.91µg/g soil of endosulfan was present as residue in the soil six months after application. There was 85% population reduction of nematode as a result of endosulfan application.

Conclusion and application of findings: Endosulfan is moderately persistent in Ibadan soil, toxic to *M.incognita* and hinders availability of some soil nutrients. Alternative insecticides that are biodegradable and environmental friendly should be sought for the control of Cocoa pests.

Key words: Endosulfan, degradation , *M.incognita, Salhbergela singularis*, Cacao.

INTRODUCTION

Agriculture has contributed immensely to rural development, provision of industrial raw materials, food security and non-oil foreign exchange earnings in Nigeria. Before the discovery and commercial exploration of crude oil in the late 1960s, agriculture accounted for a significant part of the national exports, and contributed to improved living standards and poverty reduction (CBN, 2001). Some 70% of Nigeria's annual cocoa exports are to Europe with a further 10% to the United States of America and up to 15% to Europe Nigeria is currently the fourth largest producer of cocoa (*Theobroma cacao*) in the world with 190 metric tones in 2008 (ICCO, 2007).

Studies have identified factors that have contributed to the dwindling cocoa production in Nigeria and other West Africa countries (Ollennu *et al*., 1989; Osei, 1993). Paramount among these is

the ravages caused by cocoa brown Mirid (*Sahlbergella singularis*) resulting to yield loss of about 75% if left uncontrolled. Mirid is controlled by the use of insecticides, which is applied at one-month intervals beginning from August to October. The frequency and time of application affect the effectiveness of the insecticides (Adegbola, 1993) Root-knot parasitic nematode (*M. incognita*) has also been implicated as a threat to cocoa production in Nigeria (Afolami, 1982). The use of pesticides over the years has made it possible to increase crop yields and food production (Lee, 1985). However, intensive use of pesticides results in some environmental problems such as contamination of soil and ground water. When pesticides are applied to to destroy pests and pathogens, only 15% of the applied amount hits the target, with the remaining 85% being distributed in the soil and air (Leonila, 2002). The soil is the main matrix for pesticide disposition and the bulk of pesticide residues are generally confined to the upper 5cm of the top soil (Leonila, 2002).

Pesticide residue in the soil can move from the surface when they dissolve in runoff water, or percolate down through the soil, and eventually reach the groundwater (FAO, 2000). Endosulfan 35EC is an organochlorine insecticide, which is persistent in soil and has been banned in developed countries but its use is still common in developing countries due to low level of education and poor extension services. Most farmers are only interested in protecting their crops from ravages by pests in order to get good harvest but have little concern for the detrimental effects of these pesticides on the soil environment. This study evaluated the effects of endosulfan 35EC on soil chemical properties and root-knot nematode (*Meloidogynea incognita)* population in the soil as well as determining endosulfan degradation in the soil.

MATERIALS AND METHODS

Trial site: The study was carried out on selected cocoa plantations belonging to the Cocoa Research Institute of Nigeria at Ibadan, Nigeria that have not received any pesticide treatment for the past ten years. The site is $7^0$14 N, 3^0 52 E. It is 300m above sea level. It has mean annual rainfall of 1500mm. The soil type is alfisol.

Experimental design and layout: Randomized complete block design (RCBD) with three blocks replicated three times was used. Recommended endosulfan rate (71.43ml of endosulfan 35EC in 10 liters of water) containing 0.25% active ingredient was applied on all the pods, chupons and branches of selected cocoa trees identified by tagging, while the control trees were left untreated. The trees were treated twice at 30 days interval. After the second endosulfan application, soil samples were collected with soil auger at 0-30cm soil depth on monthly basis for the six months.

Nematode assay: One hundred and seventy five grams of the collected soil sample was assayed for nematodes using the Whitehead & Hemming (1965) tray modification of the Baermann technique. Nalgene bottle was filled to the mark point with distilled water and transferred to a bowl. The sieve containing the soil sample was placed in the bowl of water and allowed to stay for 48 hours, after which the sieve and its contents were removed and the nematode extract in the bowl was poured into the Nalgene bottle. The extract was allowed to stand for 24 hours after which the extract was siphoned until there was 50ml of extract in the bottle. Twenty milliliters of the extract was pipetted into a Don Caster counting dish and placed under a Stereomicroscope for counting.

Soil assay: A portion of the collected soil samples was air-dried, sieved and kept in polythene bags for chemical analysis. The samples were leached with 1N ammonium acetate. The leachate was analyzed for exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) (Sharman et al., 1942; Schollenberger & Simon, 1945). The organic carbon was determined using Walkley and Black method (1934); total Nitrogen was determined by the Macro Kjedahl method (Bremner; 1996); available phosphorus was determined using Bray and Kurtz (1945); soil pH was measured electrometrically with glass electrode pH meter in water using soil/ water ratio of 1:2.5. The exchangeable cations were extracted by leaching 5g soil with 50ml of 1N ammonium acetate at pH 7. The potassium and sodium in the leachate were determined by flame photometer and the calcium and magnesium were determined with atomic absorption spectrophotometer. Fifty grams of the soil was weighed into sample bottles and 7ml of 0.2M NH4Cl was

added and allowed to stand for 15 minutes; then 100ml of n-hexane: acetone (1:1) was added. The soil sample and extractant was shaken for 2 hours. More of the n-hexane/acetone mix was added to wash the bottle clean. Seven hundred milliliters of distilled water was added to the filtrate in a separating funnel and shaken for ten minutes; n-hexane phase was separated from the aqueous phase. The n-hexane was dried and concentrated to 5ml with rotary evaporator.

The clean-up procedure was done loading chromatographic burette with alumina, which had been activated by drying in an oven at 130◦C for two hours to remove the moisture from the alumina. The 5ml extract was poured into the column and eluted with 30ml of n-hexane containing 1% acetone. The eluted sample was evaporated to dryness. The residue was dissolved in 5ml n-hexane and 1ml was injected into Agilent 6890 gas chromatograph (series II) with electron capture detector.

Data analysis: The data collected were subjected to analyses by descriptive statistics and T-test at 5% probability level. Mean values of three replicates were used in all the analysis.

RESULTS AND DISCUSSION

Available phosphorus ranged from 4.67-8.77ppm in the treated soil and 4.02-6.27ppm in the untreated control (table 1). No significant difference was detected between the treated and the untreated soil, and a decrease in P was observed during the trial in both soils. Potassiun content of the treated soil ranged from 0.57 – 0.79 cmol/kg soil and 0.59 – 1.21 cmol/kg In the untreated soil (table 1) . Statistical analysis indicated that the untreated soil had significantly higher K content than the treated soil in the first two months after endosulfan application. The treated soil had more K in the third month and thereafter the untreated soil had significantly higher content in the 4th and 5th month after application. There was generally an irregular pattern of potassium distribution in the soil.

Table 1: Effect of endosulsulfan on available P and Potassium in soils at Ibadan, Nigeria.

	Available P (ppm)			K (cmol/kg)		
MAA	**Control**	**Treated**	**T-test**	**Control**	**Treated**	**T-test**
1	6.27±0.09	8.77± 0.01	NS	0.71±0.01	0.67±0.06	*
2	5.87± 0.22	4.67± 0.02	NS	0.59±0.02	0.57±0.03	*
3	4.02± 0.71	6.08± 0.01	NS	0.63± 0.01	0.74±0.01	NS
4	4.51± 0.31	6.01± 0.01	NS	0.73±0.41	0.63±0.04	*
5	5.42± 0.03	5.63± 0.03	NS	1.21±0.01	0.67±0.02	*
6	5.01± 0.12	4.62± 0.02	NS	0.73±0.01	0.79±0.01	*

MAA: Month after endosulfan application. NS: Not significant, ± : Standard deviation, * : Significant at 5%

Sodium content of the treated soil ranged from 0.61 - 0.82 cmol/kg soil while it ranged from 0.70-0.87 cmol/kg in the control soil (table 2). Sodium content in the treated soil significantly decreased (P≤0.05) for the first 3 months after endosulfan application, before increasing in the 4th and 5th month, though not significantly. On the average, endosulfan reduced sodium availability in the soil. This may be the result of the decrease in pH in the treated soil(Table 4). When the pH of any soil drops there may be an increase in the concentration of hydrogen. Calcium content of the treated soil ranged from 3.58-4.73 cmol/kg while the untreated control soil ranged from 3.68-5.48 cmol/kg. There was significant decrease in calcium content of the treated soil compared to the untreated control in all the months of investigation except in the 6th month when the calcium content of the treated soil was higher than the control though not significantly.

Table 2: Effect of endosulfan on soil sodium and calcium levels at Ibadan, Nigeria.

	Na (cmol/kg)			Ca (cmol/kg)		
MAA	**Control**	**Treated**	**T-test**	**Control**	**Treated**	**T-test**
1	0.87±0.02	0.82±0.05	*	3.87±0.03	3.58±0.06	*
2	0.73±0.04	0.61±0.02	*	4.47±0.02	4.02±0.04	*
3	0.76±0.03	0.70±0.03	*	5.48±0.02	4.73±0.02	*

4	0.70±0.01	0.80±0.02	NS	4.35±0.03	4.06±0.04	*
5	0.81±0.02	0.82±0.04	NS	5.24±0.04	4.41±0.02	*
6	0.78±0.04	0.73±0.03	*	3.68±0.03	4.20±0.04	NS

MAA: Month after endosulfan application, NS : Not significant, ± : Standard deviation, * :Significant at 5%

Iron content of the treated soil ranged from 3.83-6.33 cmol/kg soil and from 1.74-6.69 cmol/kg soil in the untreated soil (table 3). Fe content in the treated soil was significantly higher than in the untreated soil throughout the months of investigation except in the 6th month after application. This might be the influence of the sulpho- group in the structure of endosulfan which on getting to the soil solution might have partially ionized to weak sulphuric acid and slightly lowered the soil pH (table 4), which eventually could have led to the solubility of Iron.

Magnesium content of the treated soil ranged from 3.30-4.80 cmol/kg soil and from 3.23-4.56 cmol/kg in the untreated soil (table 3). . Magnesium in the treated soil was significantly higher than the untreated control in the 2nd and 3rd month (p≤ 5%) after application of endosulfan. It decreased in the treated soil in the 4th month, increased in the 5th month and again decreased in the 6th month. On the overall, the distribution of magnesium in the soil did not follow a regular pattern, thus it can be said to have been influenced by endosulfan addition.

Table 3: Effect of endosulfan on Magnesium and Iron content in soil at Ibadan, Nigeria.

	Mg (cmol/kg)			Fe (cmol/kg)		
MAA	**Control**	**Treated**	**T-test**	**Control**	**Treated**	**T-test**
1	4.04±0.16	4.53± 0.21	NS	4.21±0.33	4.53±0.22	*
2	4.14± 0.12	4.44± 0.23	*	4.70± 0.21	5.21±0.23	*
3	3.23± 0.11	4.80± 0.30	*	2.13± 0.21	3.84± 0.31	*
4	4.94± 0.21	4.71± 0.20	NS	3.85± 0.40	4.76 ±0.40	*
5	4.56± 0.13	4.75± 0.32	NS	1.74±0.09	4.17±0.34	*
6	3.44± 0.09	3.30± 0.11	NS	6.60 ± 0.18	6.33±0.25	NS

MAA: Month after endosulfan application, NS : Not significant, ± : Standard deviation, * :Significant at 5%

The pH of the treated soil ranged from 6.91-6.98 while it ranged from 6.84-7.24 in the untreated soil (table 4).There was significant reduction in pH values of the treated soil compared with the untreated soil in the first four months after endosulfan application, followed by an insignificant increase in pH of the treated soil in the fifth month. Endosulfan is sensitive to moisture, acids and alkali and will undergo slow hydrolysis producing sulfur dioxide (SO2) and endosulfan diol via the intermediate endosulfan sulfate (FAO/WHO, 1968; Martens, 1977). The sulpho group in the structure of endosulfan, on getting to the soil solution, might have undergone ionization and reacted with the soil water to form weak sulphuric acid. This chemical change is enough to alter the soil chemical equilibrium and consequently increased the population of hydrogen ions thereby, lowering the soil pH.

Organic carbon of the treated soil ranged from 3.10-3.57 % and from 2.91-3.44% in the untreated control soiland there was no significant difference between the treated soil and the control throughout the period of investigation.

Table 4: Effect of endosulfan on soil pH and Organic Carbon in Ibadan, Nigeria.

	pH			Organic carbon (%)		
MAA	Control	Treated	T-test	Control	Treated	T-test
1	7.11±0.23	6.98±0.62	*	3.37±0.07	3.57±0.06	NS
2	7.06±0.62	6.91±0.52	*	3.44±0.06	3.52±0.04	NS
3	7.24±0.03	6.96±0.53	*	3.19±0.07	3.20±0.06	NS
4	6.97±0.89	6.90±0.32	*	3.17±0.03	3.10±0.07	NS
5	6.99±0.43	6.93±0.56	*	3.23±0.02	3.25±0.02	NS
6	6.84±0.73	6.94±0.23	NS	2.91±0.01	3.10±0.05	NS

MAA: Month after endosulfan application, NS : Not significant at 0.05, * : Significant at 0.05%, ± : Standard deviation

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Table 5: Effect of endosulfan on soil total Nitrogen at Ibadan, Nigeria.

	Nitrogen (%)		
MAA	**Control**	**Treated**	**T-test**
1	0.32±0.02	0.34±0.02	NS
2	0.33±0.03	0.32±0.03	NS
3	0.30±0.01	0.31±0.04	NS
4	0.31±0.06	0.29±0.02	NS
5	0.28±0.04	0.31±0.05	NS
6	0.28±0.06	0.29±0.07	NS

MAA: Month after endosulfan application, NS: Not significant at 0.05%, *: Significant at 0.05%, ±: Standard deviation

Nitrogen content of the treated soil ranged from 0.29-0.34% and from 0.28-0.33% in the untreated control. and there was no significant difference between the treated soil and the control throughout the period of investigation (table 5). This suggests that application of endosulfan in the control of mirid may not reduce Nitrogen levels in the soil

The result in figure 1 showed that 84% of the root-knot nematode population (*Meloidogyne spp.*) was eliminated by the pesticide in the first month 78% in the second month, 76% in the third month, 71% in the fourth month, 66% in the fifth month and 64% in the sixth month. This is an indication of high toxicity of the insecticide on the parasitic nematode. Endosulfan has been reported to be toxic to earthworms, causing a significant reduction in the growth rate (Mosleh *et al*., 2003). It is also toxic to soil micro arthropods (Joy & Chakravanty 1991), micro organisms, zooplanktons (Dolorenzo *et al*., 2002), phytoplanktons, soil algae, actinomyceres, and bacterial colonies (Romeo & Quijano, 2000) . This result shows that endosulfan has more than one function, as it effectively controls both insect pest (mirid) and the root-knot nematode in the soil.

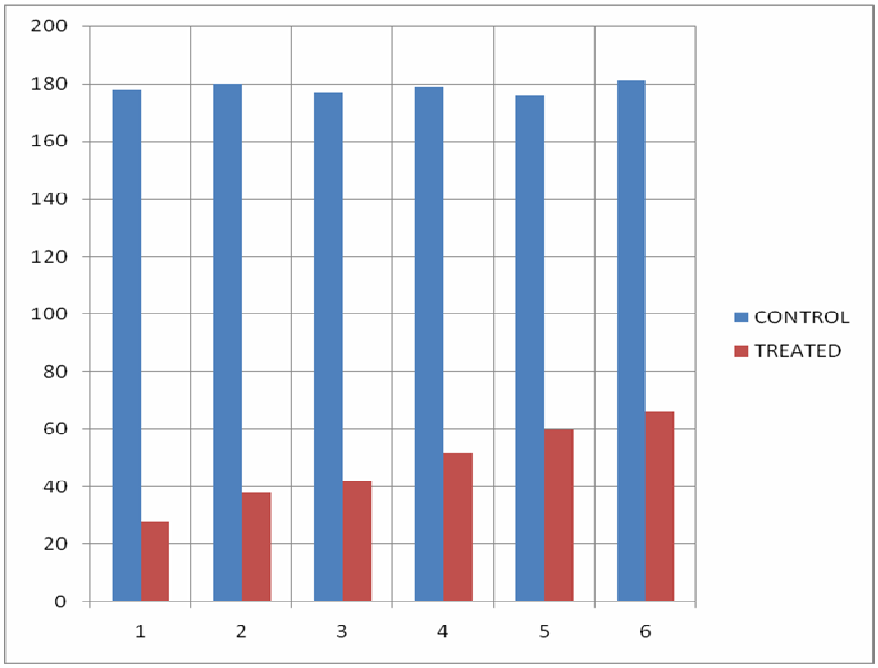

Figure 1: Effect of endosulfan application on root-knot nematode population

Obtained result of degradation of endosulfan in Ibadan soil is presented in figure 2. At one month after the application of endosulfan, 11.33mg/kg soil was left in the soil as residue, 6.34mg/kg soil was left as residue at two months after application, 4.91mg/kg at three months after application of endosulfan, 3.91mg/kg, 3.30mg/kg and 2.93mg/kg soil at four, five and six months respectively after insecticide application. The result showed that endosulfan is persistent in Ibadan soil.

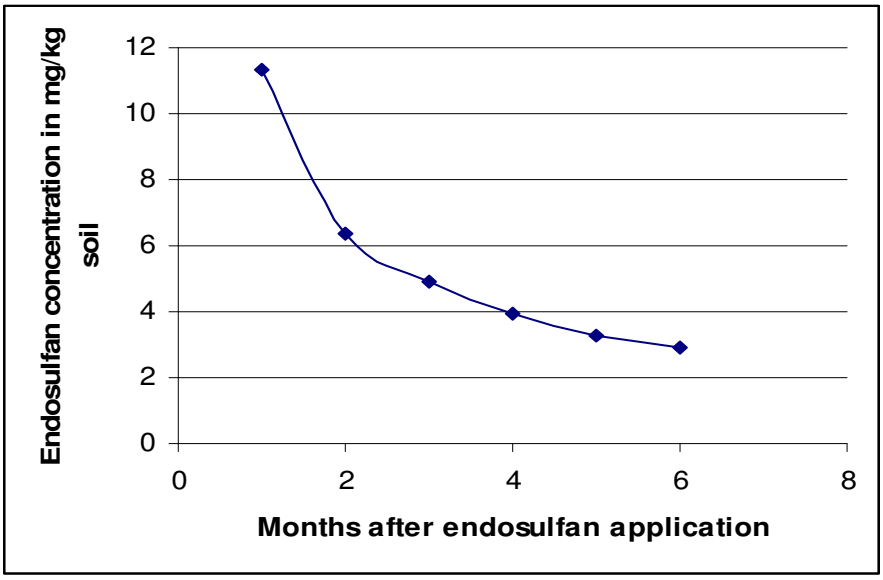

Figure 2: Degradation of endosulfan in Ibadan soil.

CONCLUSION

The results of this study showed that endosulfan 35EC can increase soil acidity; reduce soil available potassium, sodium and calcium. However, these parameters remain within the range required for cocoa growth in the tropics It is also evident that endosulfan 35EC residue has no adverse effect on available phosphorus, organic carbon and nitrogen content of the soil. The use of endosulfan in cocoa cultivation serve a dual purpose of controlling mirid as well as controlling nematode (*Meloidogynea spp*). Based on the persistence of endosulfan in the soil and its toxicological effects on soil microflora and microfauna, the use of endosulfan in the control of mirid attack on cocoa should discontinue. Other environmentally friendly and easily biodegradable insecticides should be used on cocoa at minimal doses which will not leave any residue on the crop should be sought for.

REFERENCES

Adegbola MOK (1993). Determination of the most suitable frequency and time of fungicide spraying schedule for adoption in the control of Phytophthora black pod (pod rot) disease of cacao. Proceedings of the 11th International Cocoa Research Conference, Yamoussoukro, Cote d'Ivoire. 18-24

Black CA (Ed) 1965 Methods of soil analysis. Agronomy No 9 part 2 American Soc. Agronomy Madison Wincousin.-

Bray RH and Kurtz, 1945: Determination of total organic and available forms of phosphorus in soils. Soil Sc. 59: 39-45.

CBN (Central Bank of Nigeria) (2001) Statistical bulletin vol 5 No 1

Delorenzo. ME, Taylor LA, Lund SA, Pennington PL,Strozier ED and Fulton MH (2002) Toxicity and potential of agricultural pesticide endosulfan in phytoplankton and zooplankton. Arch. Environ. Contam. Toxicol. 42(2):173-81

FAO (2000), Assessing Soil Contamination: A Reference Manual. FAO Pesticide Disposal Series. Food and Agriculture Organization of the United Nations, Rome.

Joy VC, Chakravarty P.P (1991) Impact of insecticide on non target micro arthropod fauna in agricultural soil. Ecotoxicol. Environ. Sat; vol 22, ISS 1, Pg 8-16

Lee KE (1985) Earthworms Their Ecology and Relationships with Soils and Land Use. Academic Press: Australia.

Leonila MV. (2002) Impact of agrochemical on soil and water quality. National crop protection center, University of the philipines at Los Banos.

Mosleh YY, Paris-Palacois, Couderchet M Vernet G (2003) Acute and sub-lethal effects of two insecticides on earthworm (lumbricus terrestris L) under laboratory conditions. Environ Toxicol 22(2) 73-6

Ollenu LA, Owusu GK, Thresh JM (1989). Spread of cocoa swollen shoot virus to recent plantings in Ghana. Crop Prot. 8:251-264.

Osei, JK. (1993). Construction of a low density linkage map of Theobrma cacao L. using random amplified DNA markers. Ph.D. Thesis. Univ. of Pensylvania.

Pimentel, D and Levitan, L (1986) Pesticides: amounts applied and amounts reaching pests. BioScience 36, 86-91.

Romeo F. and Quijano, M.D (2000) Risk assessment in a third world reality. An endosulfan case history. International journal of occupational and environment health vol. 6, No 4

Thompson and Troech (1978): Soils and soils fertility 4th ed. Mc Graw-Hill publication USA

Whitehead, A G (1969). Nematodes attacking coffee, tea and cocoa and their control. In Nematodes of Tropical Crops, ed. J. E. Peachey, pp. 236-50. Tech. Commun. No. 40, Commonw. Bureau Helminth.