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Effects of agrochemical application on the diversity and abundance of soil macro-fauna in cocoa-based (*Theobroma cacao*) agroforestry systems in Cameroon

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Cocoa farmers' excessive use of agrochemicals in cocoa agroforests has major repercussions on soil organisms, which play a great role in soil fertility enhancement. This study was carried out to examine the relationship between agrochemical use and soil macro-fauna diversity and abundance in cocoa agroforests in Cameroon. A mixed research approach was used, and data were analyzed using descriptive and inferential statistical tools. It was found that the main types of agrochemicals used by cocoa farmers in cocoa-based agroforestry systems were fungicides (100%), insecticides (100%), and herbicides (36.7%). The categorization of the major types of agrochemicals used by cocoa farmers revealed that, two types of herbicides, eight types of fungicides, and nine types of insecticides were used by cocoa farmers in cocoa-based agroforestry systems. Most cocoa farmers perceived that all the agrochemicals lead to a decrease in soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. Chi-square test statistic results ($X2 > 78$, $p<0.05$) showed that cocoa farmers' perceptions of the effects of agrochemicals on the diversity and abundance of soil macro-fauna in cocoa-based agroforestry systems differed significantly across the main types of agrochemicals (herbicides, fungicides, and insecticides). Correlation and regression analyses showed the existence of a statistically significant ($p<0.05$) inverse non-causal and causal relationship respectively between most agrochemicals and soil macro-fauna diversity and abundance in cocoa-based agroforestry systems, implying that the use of these agrochemicals leads to a reduction in soil macro-fauna diversity and abundance in cocoa agroforests. Thus, it is recommended that measures be taken to reduce the use of agrochemicals in cocoa agroforests in order to safeguard the diversity and abundance of soil macro-fauna in these systems.

Key words: Agrochemicals, soil fauna diversity, soil fauna, soil, agroforestry, cocoa, farmers, Cameroon

INTRODUCTION

Cocoa is a major cash crop cultivated in tropical regions of the world (Rice and Greenberg, 2000; Duguma et al., 2001; Wartenberg et al., 2017; Wartenberg et al., 2020; Dahlsjo et al., 2020). The cultivation is done mainly by smallholder farmers who make up over 90% of cocoa farmers (Vaast and Somarriba, 2014; Vanhove et al.,

2016; Prayogo et al., 2019; Niether et al., 2019). These smallholder farmers are often resource poor, and use mainly rudimentary production techniques (Tankou, 2015). The cocoa production system in these tropical countries is bedeviled by poor infrastructural facilities, aging farmers and farms, limited credit facilities, inadequate land, few and unstable markets, and many other hurdles which have pushed many cocoa farmers to abandon their cocoa farms for alternative sources of employment (Oke and Odebiyi, 2007; Utomo et al., 2016; Suarez et al., 2018; Oliveira et al., 2018; Suarez et al., 2019). The cocoa sector therefore needs major revamping across the tropics in order to ensure sustained production.

West and Central Africa constitutes one of the major cocoa production basins in the world. Countries like Ghana, Ivory Coast, Cameroon and Nigeria dominate the cocoa production sector in West and Central Africa (Duguma et al., 2001; Oke and Odebiyi, 2007; Asare et al., 2014). However, challenges linked to poor infrastructure, lack of credit facilities, aging cocoa farms and farmers, limited markets and others have discouraged many cocoa farmers causing the abandonment of cocoa farms (Vaast and Somarriba, 2014).

In Cameroon – a major cocoa producing country in West and Central Africa, cocoa production has been dwindling enormously (Nfinn, 2005; Laird et al., 2007; Jagoret et al., 2011, 2012, 2014, 2018; Essougong et al., 2020). Lack of investment in the sector and poor farming practices by cocoa farmers have led to declining cocoa yields (Kimengsi and Azibo, 2013; Kimengsi and Tosam, 2013; Tankou, 2015). With a drop in cocoa yields, cocoa farmers have resorted to the use of agrochemicals in their cocoa farms in a frantic bid to increase cocoa yields (Alemagi et al., 2015; Sonwa et al., 2008; Mahob et al., 2014; Pouokam et al., 2017; Mukete et al., 2018). The excessive use of these agrochemicals in cocoa agroforests has major repercussions on soil organisms, which play a great role in soil fertility enhancement. It was therefore within this backdrop that this study sought to assess the perceptions of cocoa farmers pertaining to the effects of agrochemical application on the diversity and abundance of soil macro-fauna in cocoa agroforests. More specifically, the study was undertaken to: (1) Identify different types of agrochemicals used in cocoa-based agroforestry systems; (2) Assess the effects of the agrochemicals on soil macro-fauna diversity in cocoa-based agroforestry systems; (3) Examine the effect of agrochemicals on the abundance of soil macro-fauna in cocoa-based agroforestry systems; (4) Assess the influence of agrochemical application on soil macro-fauna diversity and abundance in cocoa-based agroforestry systems.

MATERIALS AND METHODS

Presentation of the study site

The study was carried out in the Mungo Division of Cameroon (Figure 1). This division lies between longitude 9°17' to 10°52' E and latitude 4°22' to 6°20' N. The study area constitutes part of the Western Highlands of Cameroon – a major agro-ecological and relief region in Cameroon. The Western Highlands covers four administrative regions in Cameroon (part of the littoral, part of the south west, and the entire west and north-west regions) and has a surface area of roughly 50,000 km^2. Agriculture is the principal economic activity of the population. Owing to the predominance of agricultural activities, the Western Highlands of Cameroon (Mungo division inclusive) is considered one of the major breadbaskets of Cameroon and the Central African sub-region (Tankou et al., 2017).

The field survey proper was done in one study site that is, the Mungo Division (specifically in Melong sub-division), found in the Littoral region of Cameroon. The climate is humid tropical and the vegetation type is mostly made up of degraded forest interspersed with patches of savannah grassland. The soils are mostly ferralitic, volcanic, as well as andosols. The municipality of Melong whose chief town bears the same name, was created in 1962 by Decree No. 62/17 of 26/12/1962 (Plan Communal de Developpement – PCD Melong, 2012). It covers an area of 497 km^2 and has a population of about 102,000 persons spread in over 40 villages and in the urban areas (Plan Communal de Development – PCD Melong, 2012). It is bordered to the North by the municipality of Santchou; to the North-West by the municipality of Nguti; to the West by the municipality of Bangem; to the South-West by the municipality of Nkongsamba; to the South-East by the municipality of Baré; to the East by the Nkam river and the municipality of Kékem (Figure 1).

Data collection

To attain the objectives of the study, secondary and primary data were collected. In the case of primary, different sampling techniques were employed.

Sampling technique

The multi-stage sampling technique was used as reported in previous studies undertaken in Cameroon (Awazi and Tchamba, 2018; Awazi et al., 2019, 2020). At the first stage, the study area (Mungo division in general and Melong sub-division in particular) was purposively chosen owing to the predominance of cocoa-based (*Theobroma cacao*) agroforestry systems in the area. At the second stage, focus group discussions and key informant interviews were conducted with cocoa farmers and resource persons respectively in order to get vital information on agrochemical use in cocoa-based agroforestry systems in the study area. The focus group discussants

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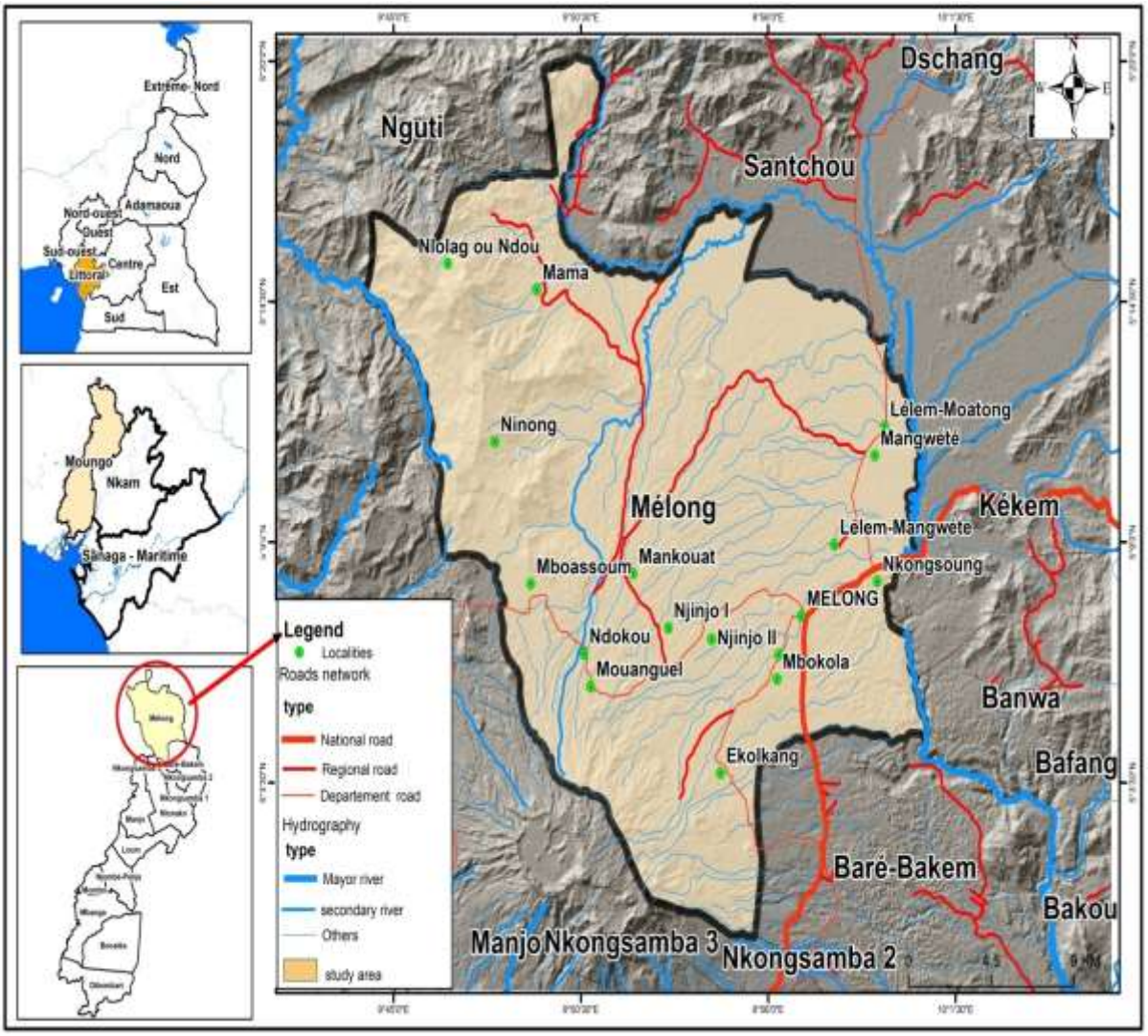

Figure 1. Map showing the study area.
Source: Authors.

were mainly farmers who had great indigenous knowledge about the cocoa-based agroforestry system. The selection of farmers to participate in focus group discussions was done with the help of agricultural extension agents who had a better mastery of the study area. The key informants who were resource persons living in the different villages in the municipality of Melong included agricultural and environmental extension agents, chiefs, quarter heads, heads of cocoa farming groups, sub-divisional delegates in the ministries of agriculture and rural development; forestry and wildlife; environment, nature protection and sustainable development. At the third stage, household surveys were conducted with farmers involved in cocoa-based agroforestry systems. This was done with the help of agricultural extension agents working on the field. The tool used to conduct the household survey was semi-structured questionnaires. The questionnaires were structured to get information on different types of agrochemicals used in cocoa-based agroforestry systems; effects of the agrochemicals on soil macro-fauna diversity in cocoa-based agroforestry systems; effects of agrochemicals on the abundance of soil macro-fauna in cocoa-based agroforestry systems; and the influence of agrochemical application on soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. The fourth and last stage involved direct field surveys on the farm plots of cocoa farmers. In this phase, both tree and macro-fauna diversity and abundance were taken examined.

Secondary data

Secondary data were collected from the following sources: the Regional, Divisional and Sub-Divisional Delegations of Agriculture and Rural Development; Forestry and Wildlife; Environment, Protection of Nature and Sustainable Development; Economy and Regional Planning; and Municipal Councils found in the Mungo Division in general and Melong sub-division in particular. Libraries in the Faculty of Agronomy and Agricultural Sciences; Scientific

Table 1. Agrochemicals used by cocoa-farmers in cocoa-based agroforestry systems.

Agrochemical	Frequency (n)	Percentage	X^2	p-level
Herbicides	110	36.7		
Fungicides	300	100	5.29^{ns}	0.638
Insecticides	300	100		

^{ns} not statistically significant.

Table 2. Categorized agrochemicals used by cocoa-farmers in cocoa-based agroforestry systems.

Major categories and types of agrochemicals used by cocoa farmers		
Herbicides	**Fungicides**	**Insecticides**
Glyphosate	Nordox	Methyl
Paraquat	Kocide	Endosulfan
	Caocobre	Cypermethrin
	Ridomil	Imidacloprid
	Fydrox	Fenobucarp
	Maneb	Cartap
	Mancozeb	Chlorpyriphos
	Metalaxyl-M	Diazinon
		Thiamethoxam

publications or articles, books and book chapters both online and offline; different websites on the internet equally served as sources for the collection of secondary data.

Primary data

Primary data was collected through household surveys, direct field surveys as well as direct field observations.

Household surveys

Household surveys were conducted with farmers practicing cocoa-based agroforestry systems in order to ascertain their perceptions pertaining to the use of agrochemicals and its impacts on soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. During household surveys, semi-structured questionnaires were administered to 300 cocoa-based agroforestry practitioners in selected villages in the Municipality of Melong. The questionnaires were tailored to obtain information on different types of agrochemicals used in cocoa-based agroforestry systems; effects of the agrochemicals on soil macro-fauna diversity in cocoa-based agroforestry systems; effects of agrochemicals on the abundance of soil macro-fauna in cocoa-based agroforestry systems; and the influence of agrochemical application on soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. The selection of cocoa farmers was done with the aid of agricultural and environmental extension officials working on the field in the Mungo Division in general and Melong administrative district in particular. The household survey of 300 farmers was complemented with focus group discussions, and key informant interviews in order to ascertain the truthfulness of cocoa farmers' perceptions.

Data analysis

Descriptive and analytical/inferential statistics were computed using Microsoft Excel 2007 and SPSS 17.0. The main descriptive statistics computed were charts, graphs, tables as well as percentage indices, while analytical/inferential statistics computed were Spearman's correlation coefficient, Chi-Square test statistic, and logistic regression. The analytical/inferential statistics were used based on the normality of the data obtained as well as the types of variables. Analytical/inferential statistics showed the causal and non-causal relationship existing between agrochemicals application in cocoa agroforests and soil macro-fauna diversity and abundance in cocoa-based agroforestry systems.

RESULTS

Identified and categorized agrochemicals used in cocoa-based agroforestry systems

The different agrochemicals used by cocoa farmers in cocoa-based agroforestry systems showed no significant difference (Table 1). From Table 1, it is seen that the main types of agrochemicals used by cocoa farmers in cocoa-based agroforestry systems were fungicides (100%), insecticides (100%), and herbicides (36.7%). Chi-square test statistic (X^2 = 5.29, p>0.05) showed no significant difference in cocoa farmers' use of the three major agrochemicals. As seen on Table 2, the categorization of the major types of agrochemicals used by cocoa farmers revealed that, two types of herbicides,

Table 3. Agrochemical application and its effects on soil macro-fauna diversity in cocoa-based agroforestry systems.

Agrochemical	Effect on soil macro-fauna diversity						X^2	p-level
	Increase in diversity		Stayed the same		Decrease in diversity			
Herbicides	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**		
Glyphosate	5	4.5	15	13.6	24	21.8	78.3*	0.000
Paraquat	10	9.1	15	13.6	30	27.3		
Fungicides	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**		
Nordox	15	5	45	15	60	20		
Kocide	7	2.3	23	7.7	60	20		
Caocobre	25	8.3	35	11.7	90	30		
Ridomil	15	5	40	13.3	125	41.7	90.5*	0.000
Fydrox	5	1.7	10	3.3	30	10		
Maneb	25	8.3	50	16.7	120	40		
Mancozeb	8	2.7	40	13.3	162	54		
Metalaxyl-M	3	1	10	3.3	17	5.7		
Insecticides	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**		
Methyl	14	4.7	30	10	151	50.3		
Endosulfan	20	6.7	35	11.7	95	31.7		
Cypermethrin	14	4.7	50	16.7	86	28.7		
Imidacloprid	17	5.7	48	16	115	38.3	110.7*	0.000
Fenobucarp	11	3.7	30	10	79	26.3		
Cartap	10	3.3	35	11.7	45	15		
Chlorpyriphos	4	1.3	20	6.7	21	7		
Diazinon	2	0.7	12	4	16	5.3		
Thiamethoxam	1	0.3	3	1	11	3.7		

*, Significant at 5% probability level.

eight types of fungicides, and nine types of insecticides were used by cocoa farmers in cocoa-based agroforestry systems.

Effect of agrochemical application on the diversity of soil macro-fauna in cocoa-based agroforestry systems

Cocoa farmers' perceptions of the effects of agrochemical use on the diversity of soil macro-fauna in cocoa-based agroforestry systems varied significantly (Table 3). Table 3 shows that for the three main types of agrochemicals (herbicides, fungicides, and insecticides), most cocoa farmers perceived that all the agrochemicals lead to a decrease in soil macro-fauna diversity in cocoa-based agroforestry systems. Very few cocoa farmers perceived that the use of these agrochemicals on cocoa farms has led to an increase in soil macro-fauna diversity in cocoa-based agroforestry systems.

As seen on Table 3, Chi-square test statistic results (X^2 > 78, p<0.05) showed that cocoa farmers' perceptions of the effects of agrochemicals on the diversity of soil macro-fauna in cocoa-based agroforestry systems differed significantly across the different main types of agrochemicals (herbicides, fungicides, and insecticides).

Effect of agrochemical application on the abundance of soil macro-fauna in cocoa-based agroforestry systems

The perceptions of cocoa farmers pertaining to the effects of agrochemical use on the abundance of soil macro-fauna in cocoa-based agroforestry systems was varied (Table 4). From Table 4, it is seen that, for the three main types of agrochemicals (herbicides, fungicides, and insecticides) used by cocoa farmers, most of the farmers perceived that the use of these agrochemicals has led to a decrease in soil macro-fauna abundance in cocoa-based agroforestry systems. Very few cocoa farmers perceived that the use of agrochemicals in cocoa-based agroforestry systems has led to an increase in soil macro-fauna abundance. Chi-square test statistic results (X^2 > 65, p<0.05) indicated that the perceptions of cocoa farmers with respect to the effects of agrochemicals application on soil macro-fauna abundance in cocoa-based agroforestry systems differed

Table 4. Agrochemical application and its effects on soil macro-fauna abundance in cocoa-based agroforestry systems.

Agrochemical	Effect on soil macro-fauna abundance						X^2	p-level
	Increase in abundance		Stayed the same		Decrease in abundance			
Herbicides	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**		
Glyphosate	4	3.6	16	14.5	24	21.8	65.1*	0.000
Paraquat	5	4.5	15	13.6	35	31.8		
Fungicides	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**		
Nordox	15	5	40	13.3	65	21.7		
Kocide	10	3.3	13	4.3	67	22.3		
Caocobre	15	5	40	13.3	95	31.7		
Ridomil	15	5	35	11.7	130	43.3	91.8*	0.000
Fydrox	5	1.7	15	5	25	8.3		
Maneb	15	5	55	18.3	125	41		
Mancozeb	17	5.7	23	7.7	170	56.7		
Metalaxyl-M	2	0.7	8	2.7	20	6.7		
Insecticides	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**		
Methyl	7	2.3	33	11	155	51.7		
Endosulfan	15	5	35	11.7	100	33.3		
Cypermethrin	12	4	48	16	90	30		
Imidacloprid	15	5	48	16	117	39	101.4*	0.000
Fenobucarp	9	3	31	10.3	80	26.7		
Cartap	7	2.3	33	11	50	16.7		
Chlorpyriphos	4	1.3	10	3.3.	31	10.3		
Diazinon	3	1	9	3	18	6		
Thiamethoxam	2	0.7	4	1.3	9	3		

*Significant at 5% probability level.

significantly (Table 4).

Influence of agrochemical application on soil macro-fauna diversity and abundance in cocoa-based agroforestry systems

Correlation and regression analyses showed the existence of an inverse non-causal and causal relationship respectively between agrochemical application and soil macro-fauna diversity and abundance in cocoa-based agroforestry systems (Table 5).

For herbicides, the application of all two types on cocoa farms (Glyphosate and Paraquat) had a statistically significant ($p<0.05$) inverse non-causal and causal relationship with soil macro-fauna diversity and abundance in cocoa-based agroforestry systems (Table 5). For fungicides, the application of five types on cocoa farms (Nordox, Caocobre, Ridomil, Maneb, and Mancozeb) had a statistically significant ($p<0.05$) inverse non-causal and causal relationship with soil macro-fauna systems (Table 5). Concerning insecticides, the application of five types on cocoa farms (Methyl, Endosulfan, Cypermethrin, Imidacloprid and Fenobucarp) had a statistically significant ($p<0.05$) inverse non-causal and causal relationship with soil macro-fauna diversity and abundance in cocoa-based agroforestry systems (Table 5).

DISCUSSION

Identified and categorized agrochemicals used in cocoa-based agroforestry systems

The main types of agrochemicals used by cocoa farmers in cocoa-based agroforestry systems were fungicides, insecticides, and herbicides. Cocoa farmers applied two types of herbicides, eight types of fungicides, and nine types of insecticides in cocoa-based agroforestry systems. There was no significant difference in cocoa farmers' use of the three major agrochemicals, implying that cocoa farmers used almost similar types of agrochemicals. Cocoa farmers' use of almost similar types of agrochemicals could be attributed to the relative ease of access to these agrochemicals as well as diversity and abundance in cocoa-based agroforestry information sharing among cocoa farmers who belong to

Table 5. Relationship between agrochemical application and soil macro-fauna diversity and abundance in cocoa-based agroforestry systems.

Agrochemical	Soil macro-fauna diversity				Soil macro-fauna abundance			
Herbicides	**r**	**p-level**	**B**	**p-level**	**r**	**p-level**	**B**	**p-level**
Glyphosate	-0.65*****	0.000	-2.14*****	0.000	-0.62*****	0.000	-2.09*****	0.000
Paraquat	-0.68*****	0.000	-2.17*****	0.000	-0.65*****	0.000	-2.12*****	0.000
Fungicides	**r**	**p-level**	**B**	**p-level**	**r**	**p-level**	**B**	**p-level**
Nordox	-0.72*****	0.000	-3.16*****	0.000	-0.71*****	0.000	-3.08*****	0.000
Kocide	-0.01	0.864	-0.001	0.998	-0.001	0.973	-0.0001	0.999
Caocobre	-0.79*****	0.000	-3.42*****	0.000	-0.74*****	0.000	-3.11*****	0.000
Ridomil	-0.86*****	0.000	-4.02*****	0.000	-0.83*****	0.000	-4.00*****	0.000
Fydrox	-0.04	0.624	-0.002	0.927	-0.06	0.751	-0.003	0.964
Maneb	-0.87*****	0.000	-4.03*****	0.000	-0.84*****	0.000	-4.02*****	0.000
Mancozeb	-0.86*****	0.000	-4.01*****	0.000	-0.84*****	0.000	-4.02*****	0.000
Metalaxyl-M	-0.13	0.529	-0.01	0.634	-0.18	0.152	-0.08	0.251
Insecticides	**r**	**p-level**	**B**	**p-level**	**r**	**p-level**	**B**	**p-level**
Methyl	-0.61*****	0.000	-2.09*****	0.000	-0.60*****	0.000	-2.02*****	0.000
Endosulfan	-0.65*****	0.000	-2.13*****	0.000	-0.63*****	0.000	-2.04*****	0.000
Cypermethrin	-0.74*****	0.000	-3.19*****	0.000	-0.72*****	0.000	-3.05*****	0.000
Imidacloprid	-0.82*****	0.000	-4.01*****	0.000	-0.80*****	0.000	-4.12*****	0.000
Fenobucarp	-0.94*****	0.000	-4.58*****	0.000	-0.87*****	0.000	-4.27*****	0.000
Cartap	-0.08	0.628	-0.004	0.781	-0.19	0.131	-0.09	0.248
Chlorpyriphos	-0.17	0.472	-0.08	0.526	-0.17	0.172	-0.06	0.217
Diazinon	-0.07	0.891	-0.003	0.924	-0.09	0.568	-0.02	0.642
Thiamethoxam	-0.01	0.925	-0.001	0.971	-0.21	0.134	-0.09	0.259
Likelihood ratio X^2			142.75*	0.000			136.83*	0.000
Pseudo R^2			0.428				0.379	
Number of observations			300				300	

cocoa farmers' groups. Agricultural extension agents equally help to inform cocoa farmers on the types of agrochemicals to be used on their farms. Studies carried out on cocoa farming systems in Cameroon have shown that cocoa farmers use different types of agrochemicals to fight against pests, diseases and weed (Sonwa et al., 2008; Mahob et al., 2014; Tankou, 2015; Mukete et al., 2018).

Effect of agrochemical application on the diversity and abundance of soil macro-fauna in cocoa-based agroforestry systems

For the three main types of agrochemicals (herbicides, fungicides, and insecticides), most cocoa farmers perceived that all the agrochemicals lead to a decrease in soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. Agrochemicals role in the decline of soil macro-fauna diversity and density could be attributed to the fact that these agrochemicals are toxic, and thus very harmful to soil fauna in general and soil macro-fauna in particular. Different studies have been carried out showing that farmers apply several agrochemicals in their different agricultural systems (Nkamleu et al., 2007; Asogwa and Dongo, 2009; Mokwunye et al., 2012; Mahob et al., 2014; Jepson et al., 2014; Danso-Abbeam et al., 2014; Alemagi et al., 2015; Danso-Abbeam et al., 2017; Kenko et al., 2017; Pouokam et al., 2017; Oyekale, 2018; Nkemleke, 2019; Ogunjimi, 2020). However, very few studies have been undertaken in Cameroon to examine the extent of agrochemical application by cocoa farmers within cocoa agroforests, which was the main thrust of this study.

Influence of agrochemical application on soil macro-fauna diversity and abundance in cocoa-based agroforestry systems

From the findings of the study, all the agrochemicals applied by cocoa farmers in cocoa agroforests had an

inverse non-causal and causal relationship with soil macro-fauna diversity and abundance in cocoa agroforests. This implies that as the application of agrochemicals in cocoa agroforests increases, soil macro-fauna diversity and abundance reduces. This could be attributed to the toxic nature of the agrochemicals which goes to harm/kill soil macro-organisms. Most studies undertaken in cocoa agroforests (Nkamleu et al., 2007; Asogwa and Dongo, 2009; Sonwa et al., 2008; Dongo, 2009; Mokwunye et al., 2012; Mahob et al., 2014; Jepson et al., 2014; Danso-Abbeam et al., 2014; Alemagi et al., 2015; Danso-Abbeam et al., 2017; Kenko et al., 2017; Pouokam et al., 2017; Oyekale, 2018; Ogunjimi, 2020) have focused mainly on the different types of agrochemicals used by cocoa farmers with little or nothing done to assess the relationship between agrochemical use and soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. Thus, this study has opened a new research path, and therefore its originality.

Conclusion

The excessive use of agrochemicals by cocoa farmers in cocoa-based agroforestry systems has major consequences on soil organisms in general and soil macro-fauna in particular. These soil macro-fauna play a great role in soil fertility enhancement. This study was therefore carried out to examine the relationship between agrochemical use and soil macro-fauna diversity and abundance in cocoa agroforests in Cameroon. It was found that the main types of agrochemicals used by cocoa farmers in cocoa-based agroforestry systems were fungicides, insecticides and herbicides. Two types of herbicides, eight types of fungicides, and nine types of insecticides were used by cocoa farmers in cocoa-based agroforestry systems. Most cocoa farmers perceived that all the agrochemicals lead to a decrease in soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. A significant inverse relationship exists between most agrochemicals and soil macro-fauna diversity and abundance in cocoa-based agroforestry systems, implying that the use of these agrochemicals leads to a reduction in soil macro-fauna diversity and abundance in cocoa agroforests. It is recommended that measures be taken to reduce the use of agrochemicals in cocoa agroforests in order to safeguard the diversity and abundance of soil macro-fauna in these systems.

Policy recommendations

The following policy implications emerge from the findings of this study: The main types of agrochemicals used by cocoa farmers in cocoa-based agroforestry systems were fungicides, insecticides and herbicides. Policies geared towards reducing agrochemical use in cocoa agroforestry should focus on these agrochemicals.

Most cocoa farmers perceived that all the agrochemicals lead to a decrease in soil macro-fauna diversity and abundance in cocoa-based agroforestry systems. A significant inverse relationship exists between most agrochemicals and soil macro-fauna diversity and abundance in cocoa-based agroforestry systems, implying that the use of these agrochemicals leads to a reduction in soil macro-fauna diversity and abundance in cocoa agroforests. Thus policies should be put in place geared towards reducing the use of these agrochemicals in order to protect soil macro-fauna in cocoa-based agroforestry systems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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