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(Research Article)

Impact of different doses of deltamethrine on soil microbial density and crop growth

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Abstract

The effects of agrochemicals pollution on soil nutrients, soil microbes as well as plants cultivated on the soil were studied. Insecticide and herbicide were used to impact on the soil samples across concentration gradients. Bean and maize seeds were planted in separate experiments to monitor the effects of the agrochemicals on the plants. The microbial diversity and the physicochemical characteristics of the soil before and after pollution were determined using standard methods. Chlorophyll contents of the leaves were also determined after planting. Results indicated that bacterial isolates such as *Enterococcus sp* 54(40%), *Staphylococcus* sp 8(13%), *Bacillus sp* 46(34%) and *Micrococcus sp* 15(11%) and fungal isolates such as *Penicillium sp* 41(34%), *Saccharomyces sp* 67(56%), Yeast sp 4(3%), *Geotrichum sp* 6 (5%) and *Aspergillus sp* 1(1.8%) were recovered from treated and untreated soil with the percentages representing after planting. From the results, the herbicide treated soils indicated that the Total Heterotrophic Bacterial Count (THBC) increased after cultivation while the Total Heterotrophic Fungal Count (THFC) decreased after cultivation. On the other hand, the insecticides treated soils recorded a general decrease in THFC and THBC after cultivation. The total nitrogen (TN) and available phosphorus (AP) had no significant differences before and after planting while the exchangeable potassium (EP) had significant increase recorded after planting. Plants generally had poor growth characteristics recorded by stem girth and length, as well as chlorophyll content.

Keywords: Agrochemicals; Microbial density; Crop yield; Deltamethrine

1. Introduction

Microorganisms being the primary soil decomposers are also the driving key ecosystem processes such as organic matter decomposition and nutrient cycling which in turn increases plant productivity [19].

According to Federal Environmental Pesticide Control Act (FEPCA), pesticide is any substance or mixture of substances used for preventing, destroying, repelling or mitigating pests (insects, rodents, weeds, bacteria, nematodes, fungus, and other terrestrial or aquatic microorganisms) [17]. Modern agricultural practices globally use a variety of agrochemicals which includes herbicides, insecticides, nematicides and fungicides to optimize crop production [11]. However, incessant application of agrochemicals can lead to soil pollution which threatens soil microbial processes and thereby affects soil fertility [15].

The persistence of pesticides in nature is determined by physicochemical properties of the soil, nature of substrates and environmental degradation. Incessant application of biological active residues of agrochemical endangers non-target organisms. Some of these pesticides interferes in the molecular interaction between plants and N-fixing rhizobacteria thereby inhibiting the important process of biological nitrogen fixation. They also reduce the activities of soil enzymes

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which are key indicators of soil fertility. In addition, agrochemicals can affect some biological reactions such as dentrification, nitrification, mineralization of organic matter and methanogenesis [20].

Utilization of agrochemicals involves biotic and abiotic transformation processes. Biotic transformation is carried by microorganisms, while abiotic transformation involves chemical and photochemical reactions. The ability for a particular agrochemical to be degraded is determined by the structure and environmental condition it is exposed to [13].

Some pesticides breakdown faster and more easily than others, having shorter "half-lives" while some may remain longer in soil. The more recalcitrant a pesticide is, the more damage it can cause to microorganisms, soil and the whole environment [21]. Pesticides like chlordane and Paraqunt have high persistence half-life more than 100 days, while endosulfan classified as organochlorine are persistent in the soil with an estimated half-life of 9 months to 6 years. It is one of the most commonly detected pesticide in U.S water [22].

This study assesses the impact of different doses of agrochemicals of Deltamethrine on soil microbial density and crop growth of maize and bean seedlings.

2. Material and methods

2.1. Sample location and collection

Soil sample was collected from a farmland at Nekede, with GPS coordinates of $5^0 25^1$ 59.99" N Latitude and 7^0 01^1 60.00" E Longitude, Owerri West, Imo State, Nigeria. The soil is dark brown silt-loam collected from about 15-30 cm below the soil surface with a soil auger. Soil collected into a sterile polyethene bag was transported in an ice chest to the laboratory for immediate analysis. Debris and other plant materials were removed manually before sieving the soil through a 2 mm stainless steel sieve.

2.2. Deltamethrine

Deltamethrine, an agrochemical was obtained from a commercial supplier in Owerri, Imo state Nigeria. The pesticide (Deltamethrine) is amber in colour with purity of 98%.

2.3. Preparation of Deltamethrine

Nine hundred milliliters (900 ml) of water were used to dilute 100 ml of the pesticide (Deltamethrine) giving a total volume of 1000 ml (10% v/v).

2.4. Preparation and Spiking of the Soil with Deltamethrine

Forty kilometer (40 kg) of soil sample was weighed into a nursery bag. The bags were grouped into two with each made up of six (6) bags and labeled according to the agrochemical and the seeds. The experimental design is shown in Table 1.

The bags were spiked with doses (10, 20, 30, 40 and 50 ml) of each of the agrochemical. Soil without the Deltamethrine was used as control. Distilled water was sprinkled on the soil sample at two (2) days interval to ensure adequate moisture.

Table 1 Experimental design of agrochemicals and plant seeds

Chemical + Seed	Label	Number of bags
Pesticide + Beans	PB	6
Pesticide + Maize	PC	6
Soil + Seed (control)	SO	2

2.5. Isolation and identification of soil organisms

A serial dilution was prepared using the soil sample. An aliquot portion (0.1 ml) of 10^{-5} dilution was inoculated onto freshly prepared surface-dried nutrient agar (NA) and Saboraud dextrose agar (SDA) for bacterial and fungal count respectively. This analysis was carried out on the soil before and after planting.

Colonies characterization and identification was done using standard manuals [4; 12; 5; 9]. Total heterotrophic bacterial and fungal counts obtained were expressed as total colony forming unit per-gram (CFU/g) and colony spore forming unit per gram (SFU/g) respectively. The percentage occurrences (%) where determined using the expression:

$$Percentage\ occurance\ (\%) = \frac{Number\ of\ a\ specie}{Total\ number\ of\ organisms\ isolated} \times 100$$

2.6. Preparation and planting of the seeds

Thirty milliliter (30 ml) of hypo bleach was diluted in 70 ml of water to obtain 100 ml mixture and the solution was used to sterilize the seeds (beans and maize) soaked in the solution for 30 min. Thereafter, the seeds were sieved out and planted to the respective code. Growth of the plant seedlings were monitored weekly by measuring the leaf length, stem length and stem girth with a transparent meter rule.

2.7. Colony counts and growth monitoring

Microbial counts were determined weekly. Growth of the plant seedlings were monitored by measuring the leaf length, stem length and stem girth with a meter rule weekly throughout the period of the experiment.

2.8. Harvesting of plants and determination of Wet and Dry Weight

After six (6) weeks, the plants were uprooted, tied together and the sands on the roots were removed. The plants were then weighed to determine wet weight. Dry weight was obtained after air drying for one week.

3. Results and discussion

Changes in total numbers of microbial load in soil treated with different doses of Deltamethrine determined at different incubation days is shown in Fig 1. Species of fungi belonging to the genus Fusarium, Saccharomyces, Aspergillus, Penicillium, Mucor, Streptomyces and Geotrichum were isolated from both the treated and untreated soils before and after planting. The results also showed that Bacillus and Enterococcus species dominated the bacterial isolates while Saccharomyces and Penicillium species dominated the fungal isolates [14; 2; 8; 16; 1]. Fusarium, Mucor and Streptomyces species were not detected after planting.

Some organisms have the capacity to resist concentrations of agrochemicals to a particular threshold. Moulds, yeasts and certain bacteria are dominant with this trait. Fusarium, Mucor and Streptomyces species were not detected upon analysis after planting which indicates their inability to resist concentrations of the insecticides and herbicides used. This research has demonstrated that agrochemicals have significant effects on the microbial population, soil nutrients, as well as the survival of plants in the polluted soil. The fate of pesticides in the soil and the transport processes depend on the cumulative effects of the pesticide's characteristics (e.g., absorptivity, solubility, volatility and degradation rate), the soil's characteristics (e.g., texture and organic matter), the application methods used (e.g., aerial or ground) and the site conditions (e.g., topography, weather and irrigation) [18; 7; 14]. [3] had reported on the effect of pesticides on enzymatic activities of soil microorganisms. Similarly, [6] reported that the level of pesticides residues in soil used for agronomy is higher that the recommended limit.

Table 2 Physicochemical properties and microbial load of the soil sample

Granulometric composition (%)			N_{tot} mg/kg	CEC-k mg/kg	P_{tot} mg/kg	pH	Microbial load (CFU/g)	
Sand	Silt	Clay					Bacteria	Fungi
72	20	8	0.10	0.12	0.16	7.6	2.92 x 10^6	9.0 x 10^5

Key: Ntot =Total nitrogen, Ptot = Total phosphorus, CEC-K = Cation exchange capacity of potassium

The granulometric composition of the soil particles, total nitrogen, total phosphorus, cation exchange capacity of potassium and pH is shown in Table 2. The soil is rich in all the three components analysed, making the soil an excellent medium for the propagation of crops [10]. The pH was near neutral and good for soil fertility and crop yield.

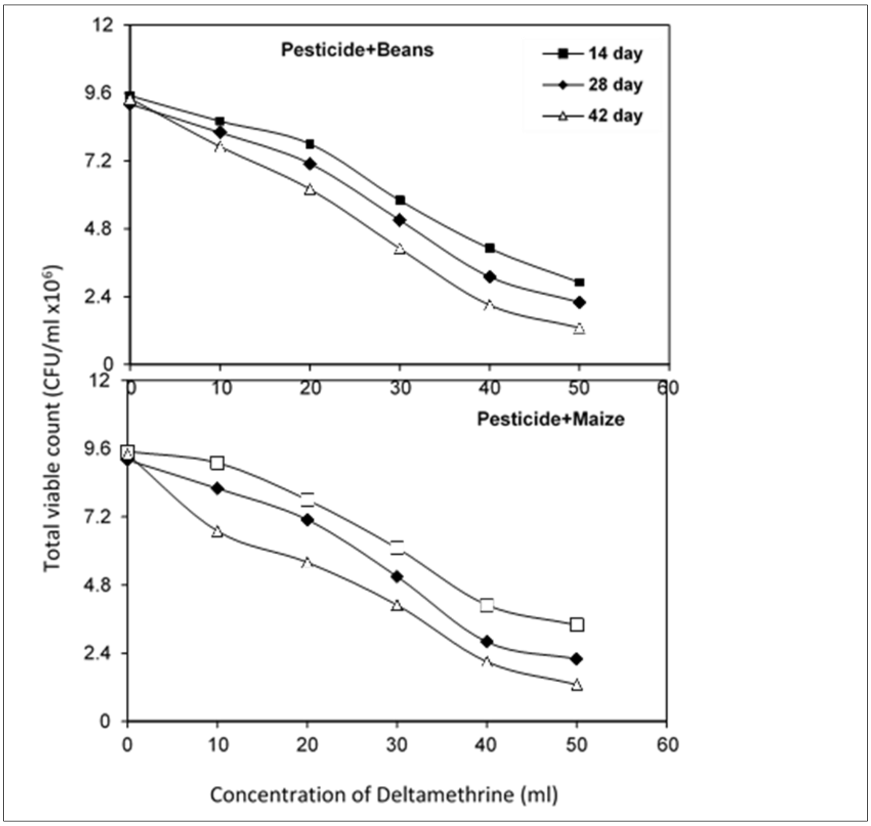

Figure 1 Changes in total numbers of microbial load in soil treated with different doses of Deltamethrine determined at different incubation days

Table 3 Percentage (%) occurrence of bacterial and fungal isolates before and after planting Isolate Period

Organism	**Before**	**After**
Bacteria	*Micrococcus* sp. 16(19)	*Micrococcus* sp. 15(11)
	Enterococcus sp. 16(19)	*Enterococcus* sp. 54(40)
	Bacillus sp. 36(44)	*Bacillus* sp. 46(34)
	Staphylococcus sp. 13(14)	*Staphylococcus* sp. 18(13)
Fungi	*Penicillum sp*. 26(24)	*Penicillum* sp. (41)
	Saccharomyces sp. 31(23)	*Saccharomyces sp.* 67(56)
	Aspergillus sp. 11(10)	*Aspergillus* sp. (0.8)
	Geotrichum sp. 7(6)	*Geotrichum* sp. 6(5)
	Fusarium sp. 11(10)	Yeast sp. 4(3)
	Streptomyces sp. 3(2)	
	Mucor sp. 18(16)	

Table 4 Effect of pesticide on the growth of maize

Pesticide [PC (%)]						
Weeks	**Parameter (cm)**	**0**	**10**	**30**	**40**	**50**
1	Leaf length	-	-	-	-	-
	Stem length	4	6	6	-	-
	Stem girth	0.4	0.6	0.4	-	-
2	Leaf length	6	11	13	-	-
	Stem length	5	7	7	4	4
	Stem girth	0.4	0.6	0.3	0.5	0.6
3	Leaf length	9	15	13	4	-
	Stem length	8	8	8	6	6
	Stem girth	1.0	1.0	1.8	0.7	0.5
4	Leaf length	10	20	20	13	4
	Stem length	8	5	10	8	8
	Stem girth	1.1	1.2	1.3	0.8	0.7
5	Leaf length	13	21	20	15	14
	Stem length	10	9	13	13	9
	Stem girth	1.6	1.6	1.6	1.6	1.1
6	Leaf length	19	26	28	28	17
	Stem length	10	10	14	13	19
	Stem girth	1.6	1.3	1.2	1.1	1.3

KEY: Control – 0

Table 5 Wet and dry weight of whole plants

PC	**wet weight (gm)**	**dry weight (gm)**	**water content (gm)**
0	20.54	11.46	9.08
PC_{10}	13.79	5.35	7.94
PC_{30}	9.63	1.19	7.94
PC_{40}	10.30	3.96	6.42
PC_{50}	10.77	4.44	6.33

KEYS: Control – 0 Pesticide in maize – PC

The figures are the total number each isolate. Numbers in parenthesis are percentage (%) of occurrence

The occurrence of bacteria and fungi in Table 3 that the soil reserves the natural microflora of the soil even after chemical treatment with slight changes in the fungal species.

Table 5 shows the effects of the pesticide application on the growth of maize plant for 6 weeks. Week one experience seed dormancy caused by higher concentration of the pesticide at 40-50%. Even after dormancy, the plants had an etiolated growth that is characterized by an increase in leave length with slender stems. The control plant had a normal growth with a normal stem size and short broad leaves. The growth pattern was significantly affected by increased concentration of the insecticide.

Table 5 shows the wet and dry weights of whole maize plants after harvest. The results showed that the pesticide treated soils had negative effects on the weights and water contents of the whole plants as seen in the differences that occurred between the control and test experiments.

4. Conclusion

The study concludes that, to minimize damage due to pesticide application to soil ecosystems, the following precautionary measures should be adopted: recommended/approved pesticides with little or no hazardous should be used in minimum effective dosage; pesticides dose/concentration should not exceed recommended application to the target area; local farmers should be properly guided on the use of agrochemicals in agriculture; biodegradable and non-recalcitrant pesticides should be used in other to safe guard the environment and soil microorganisms.

It is also recommended that a socioecological study should be carried out in communities where there has been regular use of these chemicals. In addition, a molecular study should be carried out to discover how some microorganisms resist thresholds of pesticides that are toxic to other isolates. These will help to strengthen knowledge about the spectrum of activities of pesticides.

Compliance with ethical standards

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Disclosure of conflict of interest

All the authors played vital role from the field to the laboratory analysis, collation of data and final completion of the report. No conflict was encountered through the design to the completion.

Statement of ethical approval

Standard safety protocols and ethical standards were fully complied with including Covid-19 guidelines.

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