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Effect of pesticides on maize growth, physicochemical content, and microbial activities of soil samples

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Carbon,
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Abstract — This research work determined the effect of herbicides on soil physicochemical properties, microbial activities and growth of maize plants in soils cultivated with maize in plastic pots. Percentage CO2 evolved, dehydrogenase activity and microbial biomass carbon were analysed in the soil samples. Calcium, Magnesium, potassium, Copper, Manganese, and Zinc in the samples were determined using the atomic absorption spectrophotometer. Electrical conductivity and exchangeable acidity were also determined. Plant height, the height of ear and leaf area of maize plants were determined as growth indices. The highest plant height of 72.67 cm was obtained in week 2. There were no significant differences in the pesticide-treated soil samples' organic carbon, organic matter, and total nitrogen composition. The highest total nitrogen and organic carbon values of 1.48±0.13% and 2.13±0.84% were obtained in UTLX3 and UTLX1 soil samples, respectively. The dehydrogenase activity, microbial biomass carbon and CO2 respired increased in lambda-cyhalothrin treated soils compared to the control. The highest dehydrogenase (43.40±0.10 $\mu g g^{-1} h^{-1}$), microbial biomass carbon (7.75±0.05 kgC m2) and microbial respiration (2022.50±0.50 $mg kg^{-1}$) values were obtained in LAMX3, LAMX2, and LAMX3 treated soil samples. Treatment with pesticides caused significant changes in the mineral content of the soil samples. The microbial activities of soil samples were also reduced except for lambda-cyhalothrin treated soils. Hence, herbicides should be applied in moderation to avoid the immobilization of minerals and depletion of soil microbial activities, which severely affects the mineralization and cycling of nutrients.

Subject Classification (2020):

1. Introduction

Soil is a resource that can't be renewed, and it performs varieties of functions and supports a lot of human activities and ecosystem interactions. Pesticide application is an essential component of mechanized agriculture as a result of its economic viability which has made it tend to replace the physical removal of weeds. Despite the benefits of herbicides in agricultural productivity, its consequent application exposes the soil ecosystem to chemical contaminants from which the herbicides have been manufactured. Hence, herbicide application represents a considerable side-effect of agricultural

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practices. Consequently, herbicide interaction with soil microorganisms may influence the quality and fertility of the soil by negatively affecting its physicochemical properties [1]. The impact of herbicides on soil microorganisms and their activity is governed by various factors, including the chemical and physical properties of the herbicides, the type of soil, soil properties, and environmental conditions. The soil is made up of organic matter and clay properties that control herbicide adsorption and water relations. It also provides different environments for microbial activity [2]. Soil is made up of many enzymes, such as dehydrogenases and phosphatases, which are soil quality indicators. They are active in adsorption, oxidation, reduction, hydrolysis and complexation reactions, converting organic substances into other products to maintain a balance in each soil environment without being used up in such interactions [3]. Microbial biomass and microbial respiration are also active components of each soil organic pool. This is responsible for organic matter decomposition, affecting the soil nutrient content and, consequently, the primary productivity in most biogeochemical processes in terrestrial ecosystems [4].

Maize is one of the most popular food crops on the domestic market and is grown in Nigeria's ecological zones. One of the biggest constraints to maize production is weed control which is very costly too. The most widely used weed management practices in maize, e.g., hoe weeding, pulling or slashing, usually involve much human labour input. The high cost and labour usually cause delayed and ineffective weeding, which sometimes results in many crop yield losses [5].

Currently, herbicides available for post-emergence weed control in maize have a relatively short time of action. The effectiveness of post-emergence-applied herbicides is not always satisfactory, and competition from remaining weeds can result in significant yield losses [6]. Using herbicide mixtures applied at least twice when weeds are the most sensitive can be a good solution and bring notable benefits, as in the sugar beet [7] or cereals. Chemical weed control has side effects. One of these side effects is increased production costs. Large scale use of herbicides causes soil and water pollution [8]. This work determined the effect of herbicides on soil physicochemical properties, microbial activities, and soils cultivated with maize.

2. Material and Methods

2.1. Soil sampling

Soil sampling was done in triplicates (in completely randomized design), using hand trowels to collect samples from the research field of the Biological Sciences Department, Tai-Solarin University of Education, Ijagun, Ogun State, Nigeria. The samples were collected at 5cm depth using the soil augur. The samples were then sieved with wire mesh (size<2mm). Stones, plant debris and any visible soil fauna were removed from the soil samples by sorting, after which they were thoroughly mixed with a hand trowel. Five kilograms of soils samples were then dispensed into plastic pots that had been perforated at the base to prevent the unnecessary accumulation of water. The soil was allowed to settle for seven days by incubating at 270C to allow the disturbances caused by sampling and sieving to stabilize. After the soil samples were allowed to settle, seeds of maize were planted in the plastic pots. Soil samples were collected before treatment and two weeks after treatment of soils and maize plants with the herbicides and insecticides.

2.2. Pesticides

The pesticides used (Ultramine {Dimethylammonium[2,4-dichlorophenoxy]acetate}, Paraquat {1,1-Dimethyl-4,4'-bipyridinium dichloride}, lambda cyhalothrin{(S)-_-cyano-3-phenoxybenzyl(Z)(1R,3R)-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2 dimethyl cyclopropane carboxylate and (R)-cyano-3-

phenoxybenzyl(Z)-(1S,3S)-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2 dimethylcyclopropanecarboxy late} and chlorpyrifos {O,O-Dimethyl O-3,5,6-trichloropyridin-2-yl phosphorothioate}) were obtained from a local agricultural dealership store in Ijebu-Ode, Nigeria.

2.3. Experimental design

The research was conducted using a randomized complete block design (RCBD) with three replications containing five treatments (control without treatment) and four pesticides treatments. Paraquat chloride and Ultramine were applied two weeks before planting the maize seeds, while lambda-cyhalothrin and chlorpyrifos were applied after the growth of the maize seedlings in separate plastic pots (10 litres in size). The insecticides and herbicides were applied in the following concentrations: (1) at manufacturers rate (X1) (2) at two times the manufacturers rate (X2) (3) at three times the manufacturers rate (X3). However, the growth of the maize seedlings was only measured after application at the manufacturer's rate.

2.4. Determination of plant height

Plant height was measured from the base of the maize plant at soil level to the crest of the uppermost leaf at 2, 4 and 6 weeks after sowing. Plant height was measured using a meter rule.

2.5. Determination of height of the ear

The height of the ear above ground from the collar of the stem to the node that had the first ear was also measured using a meter rule.

2.6. Determination of leaf area per plant

The length and width of all green leaves of the maize plants were measured using a meter rule at three-week intervals. The product of the length and width of each leaf were then multiplied by 0.75 to give the area for each leaf.

2.7. Determination of soil chemical properties

Soil pH was determined by the method described by Rhodes [20]. Soil characteristics, including exchangeable acidity, were determined using standard methods from the Non-Affiliated Soil Analysis Work Committee [21]. Electrical conductivity [20] was determined in 50 g of soil mixed with 50 ml of deionized water, shaken at 200 rpm for 2 h, and filtered through a filter paper (Grade 4 Whatman International Ltd, Maidstone, England). Electrical conductivity was measured on the filtered solution with an ionic probe (Orion 3 star bench-top conductivity meter Thermo Scientific).

2.8. Determination of organic matter in the soil

Percentage organic matter was determined by the method described by Page et al. [9]. Soil samples were collected and sieved through 0.5mm sieve. One gram of each soil sample was dispensed into 250 ml Erlenmeyer flasks, and 10 ml of $K_2Cr_2O_7$ solution was allowed to dissolve into each flask. Twenty millilitres of concentrated H_2SO_4 were added and swirled until the soil and reagents were mixed, then the mixture was swirled more vigorously for one minute; the flasks were then rotated and allowed to stand in a sheet of asbestos for about 30 min. One hundred millilitres of distilled water were added to each flask, followed by 3-4 drops of indicator (ferroin) and titrated with 0.5 N $FeSO_4$ solution to the endpoint, from greenish or dark green to red (maroon colour), in reflected light against a white background. The organic matter was then calculated according to using the following formula,

$$\% \text{ Organic matter} = \frac{(\text{me } K_2SO_4 - \text{me } FeSO_4) \times 0.003 \times 100 \times ƒ \times 1.729}{w}$$

w = Weight of air-dried soil

Correlation factor "ƒ" = 1.33

me = Normality of solution × millilitre of solution used.

2.9. Determination of total nitrogen content of the soil

Five grams of soil samples were digested with H_2SO_4 in the presence of $CuSO_4$ H_2O as a catalyst and K_2SO_4, which raised the digestion temperature. The ammonium content of the digest was determined by distillation with excess NaOH and absorption of the evolved NH_3 in standard HCL. The excess standard HCL were titrated against standard NaOH using methyl red as an indicator. The decrease in the multi-equivalence of acid was then determined by acid-base titration, which will measure the N content of the sample. The endpoint was then determined by a change of colour from pink to yellow [9].

2.10. Determination of available phosphorus in soil using Bray No. 1 Method

Five grams of air-dried soil samples passed through 2mm sieve, weighed into a centrifuge tube, and added 20 ml of extracting solution. The mixture was then shaken for 1 min on a mechanical shaker and centrifuged at 2000rpm for 15 minutes. Two millilitres of clear supernatant were then dispensed into a 20ml test tube with pipettes. Five millilitres of distilled water and 2ml of ammonium molybdate solution were then added. The contents were mixed, and 1 ml of $SnCl_2.2H_2O$ dilute solution was added and remixed. Percentage transmittance was measured on a Spectronic-20 electro photometer at 660 nm wavelength [10].

2.11. Mineral analysis

To 2.0 g of the soil sample, 30ml of IN NH_4OAC (ammonium acetate solution) was added, and the flasks were shaken on a mechanical shaker for two h. The mixture was centrifuged at 2000 rpm for 10 min, and the clear supernatant was decanted into 100 ml volumetric flasks. About 30 ml of ammonium acetate solution (NH_4OAC) was added twice into the flasks, shaken on a mechanical shaker for 30 min each, centrifuged at 2000 rpm, and the clear supernatant was then transferred into the same volumetric flasks respectively. The sample extract was made up to 100 ml volume with the NH_4OAC solution.

Calcium, Magnesium, potassium, Copper, Manganese, and Zinc in the samples were determined using the atomic absorption spectrophotometer fitted with a hollow cathode lamp and a fuel-rich flame (air acetylene). Sample solutions (extract) and standard solution for each mineral were injected into the atomic absorption spectrophotometer into the sample fray, and the mean signal response was recorded for each element at their respective wavelength. The concentration of the minerals was calculated [11].

2.12. Determination of microbial respiration

In separate vials, one hundred grams treated and untreated soil samples were placed in 1000 mL wide neck screw top glass jars containing 10mL of NaOH 0.1N solution. Soil samples were incubated in the dark at 25^{o}C$\pm$ 0.5. Using sterile ultra-pure water, soil moisture content was maintained at 60% water holding capacity by weighing and correcting for any weight loss. Soil CO_2-evolution was regularly (5-days interval period) estimated during the twenty-five days incubation period. CO_2 recovered in each NaOH solution was measured by titration with HCl, following the addition of $BaCl_2$. Percentage CO_2 evolved was then calculated [12].

2.13. Determination of microbial biomass carbon of the soil

Five grams of herbicide treated soil samples were fumigated with 50ml of 2:1 chloroform-ethanol in a vacuum desiccator for 24hrs. The soils that were not fumigated were used as blank. The soil sample was extracted with 40ml of 0.5M K_2SO_4 for 30 min in an oscillator at 300 rpm. The blank soils were also extracted with the 0.5M K_2SO_4, and the resulting extracts were filtered through Whatman No 42 Filter paper into a 250ml conical flask. The filtrates were then used to determine microbial carbon on a UV/V Spectrophotometer [13].

2.14. Determination of dehydrogenase activity

Six grams of soil and 6 ml of water samples were dispensed separately into 500ml conical flasks. 30ml glucose, 1ml of 2,3,5-triphenyl tetrazolium chloride (TTC) solution, and 2.5ml of distilled water were added and shaken on a shaker for 5min. The mixtures were then filtered through a double-layered filter paper into a 250ml conical flask, forming 1,3,5-triphenyl formazan (TPF). A stock solution of 0.2µmol/ml of TPF was prepared by dissolving 0.03g TPF in 500ml methanol. Working standard solutions of range 0.004 – 0.10 µmol/ml TPF were prepared from the stock solution to get the gradient factor. The absorbances of sample extract above and that of different working standard solutions were read on a UV/V Cecil Spectrophotometer at a wavelength of 485nm [14].

2.15. Statistical analysis

Data generated from this study were subjected to analysis of variance (ANOVA). Means were compared at a 5% level of significance using Duncan's multiple range tests.

3. Results and Discussion

Figure 1 shows the influence of the pesticides applied on the plant height at the manufactures rate of application. The result shows that there was a significant difference ($P \leq 0.05$) between the values of the plant height (chlorpyfos=58cm, Lambda= 45cm, Paraquat=71.37 and Ultramine= 59.9 cm) in soils treated with herbicides compared to the control (72.67 cm) at week 6. However, the plant height was significantly shorter ($P \leq 0.05$) in control than Ultramine at week 2. The soil treated with lambda showed significantly shorter height ($P \leq 0.05$) than other treatments at week 2, 4 and 6. However, in the plot treated with paraquat, the maize plant grew taller than other treatment plots at week 6. The highest plant height of 72.67 cm was obtained in week 2. In Figure 2, the results showed a significant difference ($P \leq 0.05$) between the treatments and the control at week 2, 4 and week 6 (control= 3.03 cm at week 2, 7.67cm at week 4 and 13.33 at week 6). However, the height of the ear of the control (3.03 cm) was significantly shorter ($P \leq 0.05$) than Ultramine treated plots at week 2. The height of the ear in paraquat treated soils was significantly higher ($P \leq 0.05$) at week 4 (8.33 cm) compared to other treatments, while the control plot was the highest (13.33cm) at week 6. The results in Figure 3 show a significant difference ($P \leq 0.05$) between leaf area values of the treatments and the control at week 4 and week 6. The control was significantly higher ($P \leq 0.05$) at weeks 4 and 6 (51.75 cm and 97.5 cm, respectively). However, in paraquat treated soils, the leaf area of the maize plant was significantly higher (38.75 cm^2) ($P \leq 0.05$) at week 4 compared to other treatments except for the control. The control plot had the highest (97.5 cm^2) leaf area value at week 6.

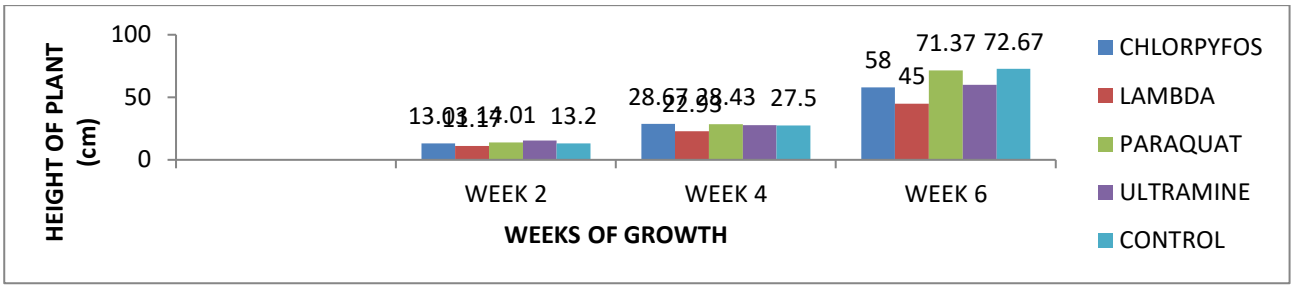

Figure 1. The effect of Chlorpyfos, Lambda, Paraquat, and Ultramine applied at the manufactures rate on maize plant height. Analysis of variance shows that values are significant at P≤0.05 and insignificant at P≥0.05.

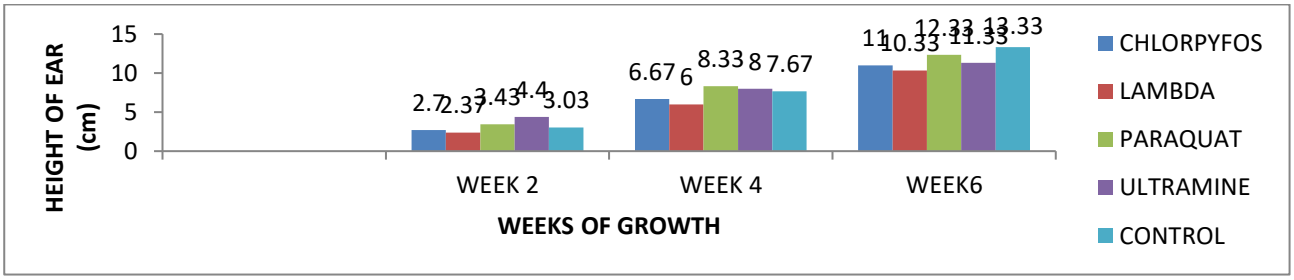

Figure 2. The effect of Chlorpyfos, Lambda, Paraquat and Ultramine applied at the manufactures rate on the height of the ear. Analysis of variance shows that values are significant at P≤0.05 and insignificant at P≥0.05.

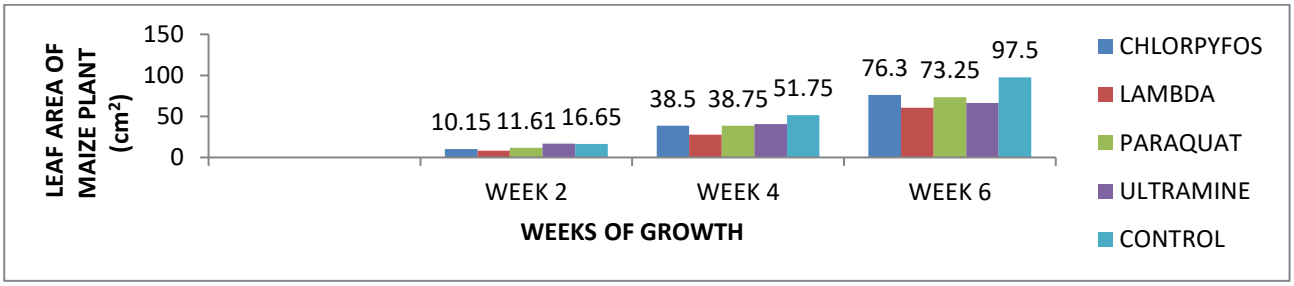

Figure 3. The effect of Chlorpyfos, Lambda, Paraquat, and Ultramine applied at the manufactures rate on maize leaf area. Analysis of variance shows that values are significant at P≤0.05 and insignificant at P≥0.05.

In Table 1, after treating soil samples with pesticides, the pH values of the pesticide-treated soil samples tended more towards acidity. There was a significant difference (P≤0.05) between the pH value of the control compared to the pesticide-treated soils. The CFLX2 soil sample recorded the lowest pH value of 6.04±0.12. There were significant differences in the pH values of UTLX1, UTLX2 and UTLX3 soil samples. PRQX2 and PRQX3 soil samples also showed a significant difference (P≤0.05) in pH values. The control soil samples recorded the highest sand composition value of 94.75±0.00%. The differences in values of silt and clay composition were not significant (P≥0.05). The highest silt and clay compositions (6.51±0.39% and 4.40±0.81%, respectively) were obtained in CFLX2 and UTLX1 soil samples, respectively. There were no significant differences in the organic carbon, organic matter, and total nitrogen composition of the pesticide-treated soil samples. The highest total nitrogen and organic carbon values of 1.48±0.13% and 2.13±0.84% were obtained in UTLX3 and UTLX1 soil samples, respectively. The highest organic matter value of 3.65±1.48% was obtained in CFLX2 soil samples. The highest and lowest average phosphorus values of 6.55±0.02 mg/kg and 4.58±1.21 mg/kg were obtained in LAMX1 and LAMX2 soil samples, respectively. The differences in the values of average phosphorus and electrical conductivity were insignificant (P≥0.05). However, there were significant

differences (P≤0.05) in the exchangeable acidity values. Soil sample UTLX3 recorded the highest exchangeable acidity and electrical conductivity values of 0.86±0.01 cmol/kg and 1.78±0.02 cmolkg$^{-1,}$ respectively.

In Table 2, there were significant differences in the K (P≤0.001), Ca (P≤0.01), Cu (P≤0.021) and Zn (P≤ 0.009) values obtained in this study. The differences in values of Mg and Na were insignificant (P≥0.05). The Ca content was highest in UTLX1 (3.80±0.16 mg/kg) soil sample, while Mg was highest in UTLX3 (1.60±0.02 mg/kg) soil sample. The highest Mn (7.52±0.07 cmolkg^{-1}), Cu (0.85±0.02 cmolkg^{-1}) and Zn (2.43±0.02 cmolkg^{-1}) values were obtained in the UTLX1 soil samples.

In Table 3, the dehydrogenase, microbial biomass carbon and microbial respiration significantly increased (P≤ 0.0001) after treatment with LAMX1, LAMX2 and LAMX3 compared to control. However, there were significant reductions (P≤ 0.0001) in the dehydrogenase, microbial biomass carbon and microbial respiration values after treatment with UTLX1, UTLX2, UTLX3, CFLX1, CFLX2, CFLX3, PRQX1, PRQX2 and PRQX3. The highest dehydrogenase (43.40±0.10 μgg^{-1}h^{-1}), microbial biomass carbon (7.75±0.05 kgCm^{-2}) and microbial respiration (2022.50±0.50 mgkg^{-1}) values were obtained in LAMX3, LAMX2, and LAMX3 treated soil samples.

Table 1. Effect of pesticides at manufacturers rate (X1), two times manufacturers rate (X2), and three times manufacturers rate (X3) on soil physicochemical properties

	pH	EA (cmolkg^{-1})	EC (cmolkg^{-1})	%TN	%OC	%OM	AVP (mg/kg)
CONT	7.21±0.00^{c}	0.56±0.00^{a}	1.37±0.00^{a}	0.44±0.00^{a}	1.35±0.00^{a}	2.33±0.00^{a}	5.52±0.00^{ab}
LAMX1	6.50±0.17^{abc}	0.75±0.03^{a}	1.61±0.15^{a}	1.08±0.41^{a}	1.79±0.35^{a}	2.94±0.46^{a}	6.55±0.02^{b}
LAMX2	6.62±0.23^{abc}	0.69±0.04^{a}	1.52±0.10^{a}	0.83±0.24^{a}	1.91±0.89^{a}	3.29±1.53^{a}	4.58±1.21^{a}
LAMX3	7.16±0.19^{ab}	0.58±0.00^{a}	1.33±0.11^{a}	0.43±0.05^{a}	1.25±0.09^{a}	2.16±0.13^{a}	5.85±0.07^{ab}
ULTX1	6.23±0.31^{a}	0.85±0.06^{a}	1.77±0.20^{a}	1.21±0.47^{a}	2.13±0.84^{a}	3.67±1.45^{a}	6.51±0.17^{b}
ULTX2	6.52±0.05^{abc}	0.80±0.04^{a}	1.69±0.04^{a}	1.14±0.05^{a}	1.40±0.03^{a}	2.42±1.05^{a}	5.29±0.03^{ab}
ULTX3	6.43±0.05^{ab}	0.86±0.01^{a}	1.78±0.02^{a}	1.48±0.13^{a}	1.92±0.45^{a}	1.92±0.45^{a}	5.94±0.55^{ab}
CFLX1	6.78±0.19^{abc}	0.60±0.15^{a}	1.42±0.30^{a}	0.98±0.55^{a}	1.36±0.62^{a}	2.79±0.61^{a}	6.10±0.27^{ab}
CFLX2	6.04±0.12^{a}	0.58±0.25^{a}	1.52±0.35^{a}	1.05±0.63^{a}	2.08±0.83^{a}	3.65±1.48^{a}	6.23±0.37^{b}
CFLX3	6.51±0.27^{abc}	0.76±0.01^{a}	1.75±0.08^{a}	0.86±0.27^{a}	1.07±0.11^{a}	1.84±0.19^{a}	5.86±0.61^{ab}
PRQX1	6.27±0.12^{a}	0.77±0.09^{a}	1.57±0.20^{a}	0.60±0.02^{a}	1.10±0.27^{a}	1.90±0.47^{a}	6.49±0.01^{b}
PRQX2	6.26±0.03^{a}	0.63±0.09^{a}	1.52±0.26^{a}	0.37±0.14^{a}	1.06±0.27^{a}	1.83±0.47^{a}	6.20±0.24^{b}
PRQX3	6.78±0.53^{abc}	0.74±0.15^{a}	1.60±0.24^{a}	1.00±0.55^{a}	2.00±0.76^{a}	3.10±0.97^{a}	6.10±0.54^{ab}

LAMX1 = lambda-cyhalothrin at manufacturers recommended dose, LAMX2 = lambda-cyhalothrin at two times manufacturers recommended dose, LAMX3 = lambda-cyhalothrin at three times manufacturers recommended dose, CFLX1= chlorpyrifos, ULTX1= Ultramine herbicide at manufacturers recommended dose UTLX2= Ultramine herbicide at two times manufacturers recommended dose, UTLX3=Ultramine herbicide at three times manufacturers recommended dose, PRQX1= Paraquat dichloride at manufacturers recommended dose, PRQX2= Paraquat dichloride at two times manufacturers recommended dose, PRQX3= Paraquat dichloride at three times manufacturers recommended dose. Values followed by the same superscript along the same vertical column are not significantly different (P≥0.05), while values followed by different superscripts along the same vertical column are significantly different (P≤0.05).

Table 2. Effect of pesticides at manufacturers rate (X1), two times manufacturers rate (X2), and three times manufacturers rate on soil minerals

	Ca ($cmolkg^{-1}$)	Mg ($cmolkg^{-1}$)	Na ($cmolkg^{-1}$)	K ($cmolkg^{-1}$)	Mn ($mgkg^{-1}$)	Cu ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)
CONT	3.16 ± 0.00^{a}	1.07 ± 0.00^{a}	0.46 ± 0.00^{ab}	1.45 ± 0.00^{a}	5.61 ± 0.00^{a}	0.38 ± 0.00^{a}	1.67 ± 0.00^{a}
LAMX1	3.61 ± 0.04^{a}	1.44 ± 0.20^{a}	0.58 ± 0.05^{ab}	1.76 ± 0.02^{ab}	7.09 ± 0.04^{ab}	0.70 ± 0.08^{bcde}	2.23 ± 0.05^{bc}
LAMX2	3.47 ± 0.08^{a}	1.33 ± 0.05^{a}	0.53 ± 0.04^{ab}	1.71 ± 0.03^{ab}	6.35 ± 0.94^{ab}	0.77 ± 0.04^{de}	2.30 ± 0.09^{bc}
LAMX3	3.29 ± 0.07^{a}	1.15 ± 0.08^{a}	0.46 ± 0.07^{ab}	1.58 ± 0.02^{ab}	6.02 ± 0.16^{ab}	0.58 ± 0.05^{abcd}	1.96 ± 0.09^{ab}
ULTX1	3.80 ± 0.16^{a}	1.49 ± 0.17^{a}	0.59 ± 0.02^{ab}	1.91 ± 0.07^{b}	7.52 ± 0.07^{b}	0.85 ± 0.02^{e}	2.43 ± 0.02^{c}
ULTX2	3.38 ± 0.06^{a}	1.48 ± 0.06^{a}	0.67 ± 0.03^{ab}	1.85 ± 0.03^{b}	7.19 ± 0.04^{b}	0.75 ± 0.02^{cde}	2.19 ± 0.05^{bc}
ULTX3	3.62 ± 0.08^{a}	1.60 ± 0.02^{a}	0.70 ± 0.04^{b}	1.88 ± 0.06^{b}	7.37 ± 0.09^{b}	0.71 ± 0.10^{bcde}	2.26 ± 0.09^{bc}
CFLX1	3.43 ± 0.16^{a}	1.32 ± 0.14^{a}	0.46 ± 0.11^{ab}	1.58 ± 0.11^{ab}	6.51 ± 0.44^{ab}	0.55 ± 0.01^{abc}	2.01 ± 0.08^{ab}
CFLX2	3.54 ± 0.36^{a}	1.34 ± 0.25^{a}	0.41 ± 0.16^{a}	1.71 ± 0.22^{ab}	6.76 ± 0.69^{ab}	0.64 ± 0.08^{bcde}	2.15 ± 0.2^{bc}
CFLX3	3.52 ± 0.25^{a}	1.48 ± 0.05^{a}	0.57 ± 0.03^{ab}	1.84 ± 0.03^{b}	7.25 ± 0.12^{b}	0.64 ± 0.00^{bcde}	2.16 ± 0.05^{bc}
PRQX1	3.52 ± 0.25^{a}	1.37 ± 0.21^{a}	0.58 ± 0.09^{ab}	1.74 ± 0.09^{ab}	7.16 ± 0.12^{b}	0.67 ± 0.06^{bcde}	2.17 ± 0.01^{bc}
PRQX2	3.50 ± 0.34^{a}	1.33 ± 0.15^{a}	0.43 ± 0.09^{a}	1.72 ± 0.10^{ab}	6.75 ± 0.57^{ab}	0.62 ± 0.01^{bcd}	2.11 ± 0.06^{bc}
PRQX3	3.39 ± 0.52^{a}	1.43 ± 0.33^{a}	0.60 ± 0.12^{ab}	1.68 ± 0.21^{ab}	6.43 ± 0.80^{ab}	0.52 ± 0.15^{ab}	1.97 ± 0.29^{ab}

LAMX1 = lambda-cyhalothrin at manufacturers recommended dose, LAMX2 = lambda-cyhalothrin at two times manufacturers recommended dose, LAMX3 = lambda-cyhalothrin at three times manufacturers recommended dose, CFLX1= chlorpyrifos, ULTX1= Ultramine herbicide at manufacturers recommended dose UTLX2= Ultramine herbicide at two times manufacturers recommended dose, UTLX3=Ultramine herbicide at three times manufacturers recommended dose, PRQX1= Paraquat dichloride at manufacturers recommended dose, PRQX2= Paraquat dichloride at two times manufacturers recommended dose, PRQX3= Paraquat dichloride at three times manufacturers recommended dose. Values followed by the same superscript along the same vertical column are not significantly different ($P\geq0.05$), while values followed by different superscripts along the same vertical column are significantly different ($P\leq0.05$).

Table 3. Effect of pesticides at manufacturers rate (X1), two times manufacturers rate (X2), and three times manufacturers rate on soil microbial activities

TREATMENT	DEHYDROGENASE ACTIVITY	MICROBIAL BIOMASS CARBON	CO_2 RESPIRED ($mgkg^{-1}$)
CONT	32.60 ± 0.10^{f}	6.75 ± 0.05^{f}	1986.50 ± 0.50^{i}
LAMX1	43.30 ± 0.10^{h}	7.45 ± 0.05^{i}	2022.50 ± 0.50^{m}
LAMX2	42.60 ± 0.10^{g}	7.75 ± 0.05^{j}	2020.50 ± 0.50^{l}
LAMX3	43.40 ± 0.10^{h}	7.25 ± 0.05^{h}	2016.50 ± 0.50^{k}
ULTX1	31.10 ± 0.30^{e}	5.75 ± 0.05^{c}	1901.50 ± 0.50^{d}
ULTX2	30.95 ± 0.25^{de}	6.15 ± 0.05^{d}	1904.50 ± 0.50^{e}
ULTX3	31.35 ± 0.15^{e}	6.45 ± 0.05^{e}	1907.50 ± 0.50^{f}
CFLX1	29.60 ± 0.10^{c}	7.05 ± 0.05^{g}	2006.50 ± 0.50^{j}
CFLX2	30.45 ± 0.15^{d}	6.55 ± 0.05^{e}	1977.50 ± 0.50^{g}
CFLX3	29.70 ± 0.10^{c}	6.95 ± 0.05^{g}	1981.50 ± 0.50^{h}
PRQX1	26.70 ± 0.10^{b}	5.25 ± 0.05^{a}	1714.50 ± 0.50^{a}
PRQX2	26.40 ± 0.10^{ab}	5.65 ± 0.05^{c}	1722.50 ± 0.50^{b}
PRQX3	26.10 ± 0.30^{a}	5.45 ± 0.05^{b}	1717.50 ± 0.50^{c}

LAMX1 = lambda-cyhalothrin at manufacturers recommended dose, LAMX2 = lambda-cyhalothrin at two times manufacturers recommended dose, LAMX3 = lambda-cyhalothrin at three times manufacturers recommended dose, CFLX1= chlorpyrifos, ULTX1= Ultramine herbicide at manufacturers recommended dose UTLX2= Ultramine herbicide at two times manufacturers recommended dose, UTLX3=Ultramine herbicide at three times manufacturers recommended dose, PRQX1= Paraquat dichloride at manufacturers recommended dose, PRQX2= Paraquat dichloride at two times manufacturers recommended dose, PRQX3= Paraquat dichloride at three times manufacturers recommended dose. Values followed by the same superscript along the same vertical column are not significantly different ($P\geq0.05$), while values followed by different superscripts along the same vertical column are significantly different ($P\leq0.05$).

In this study, treatment of soils with Ultramine resulted in increased plant height at week 2, while in paraquat treated soils, the maize plants grew taller at week 4 compared to the other soil treatments, however in the soils treated with lambda-cyhalothrin, there was reduced plant height at week 2, 4 and 6 respectively, these results are in line with the findings of Hassan et al. [15]; they reported increased height of maize crop in plots treated with herbicides to control weeds compared to plots without herbicide treatment. In this study, treatment of soil samples with pesticides resulted in reduced ear length compared to the control soil samples except in paraquat and ultramine treated soils that showed increased ear length at weeks 2 and 4. The ear length in paraquat and ultramine treated soils was later reduced compared to the control at week 6. Ali et al. [16] reported that ear length increases when adequate weed control treatments are applied, and proper herbicides are applied in maize production.

The application of the pesticides in this study resulted in a reduction of pH of soil samples, making the pH values of the soil samples tend towards acidity. The percentage soil composition showed that the soil samples contained the highest proportion of sandy soil compared to total carbon 0.53%, total nitrogen 0.06%, organic matter 0.91% and pH 8.04. The sandy soil is classified into the group of Arenosols. The persistence of pesticides depends on the chemical soil properties. The adsorption process depends on the concentration and solubility of herbicides in soil solution, ion exchange capacity, organic matter content, pH, moisture and temperature of the soil, etc. Soils with heavy mechanical composition have a higher pesticide-adsorbing capacity than light (sandy) soil. All the ultramine treated soils recorded the highest Ca, Mg, Na, K, Mn, Cu and Zn values. This might be due to the chemical reaction between the amine group and the minerals. In this study, treatment of soil samples with pesticides (lambda-cyhalothrin, chlorpyrifos, paraquat and ultramine) resulted in increased Ca, Mg, Na, K, Mn, Cu and Zn in this study. Paul et al. [17] reported that soil treatment with 2,4-D and endosulfan resulted in a significant reduction in the level of available Cu. Paul et al. [17] also reported that the insecticides used in their study stimulated a 13.9% increase in the level of available Zn on the 15th day despite the insignificant effect the insecticides had on Zn during the initial period. This indicates the process by which available Cu was is made unavailable for plant use through immobilization. The exchangeable acidity, electrical conductivity, organic matter, organic carbon, total nitrogen values were highest in ultramine treated soils. In this study, the increases observed in the organic carbon and organic matter values were insignificant.

However, Atakiru et al. [18] reported increases in the organic carbon of carbofuran treated soils until the 21st day of incubation and then decreased on the 28th day. Atakiru et al. [18] also stated that the organic carbon in paraquat treated soils increased from day 7(1.62%) to 14(2.45%), followed by a decrease at day 21(1.94%) but later increased at day 28(2.48%). The dehydrogenase activity, microbial biomass carbon and CO_2 respired increased in all lambda-cyhalothrin treated soils compared to the control. Latif et al. [19] also reported increased CO_2 respired in soils treated with insecticides such as thiodicarb, Lambda-Cyhalothrin, abamectin and cypermethrin. Dehydrogenase activity, microbial biomass carbon and CO_2 respired decreased significantly compared to control in all the ultramine, chlorpyrifos and paraquat treated soils. Dehydrogenase activity, microbial biomass carbon and CO_2 respired recorded the lowest values in paraquat treated soils. Lambda-cyhalothrin treated soils recorded the highest dehydrogenase activity, microbial biomass carbon, and CO_2 respired values. Similar results were obtained by Cycon and Kaczriska [20], who reported that the treatment of soil samples with the fungicide dithianon resulted in a significant decrease in substrate-induced respiration only at a concentration of 28.0 mg kg^{-1} 1 day after application.

4. Conclusion

Treatment with pesticides caused significant changes in the mineral content of the soil samples. The microbial activities of soil samples were also reduced except for lambda-cyhalothrin treated soils. Hence the application of herbicides should be made in moderation to avoid immobilization of minerals and depletion of soil microbial activities which in turn severely affects mineralization and cycling of nutrients.

Author Contributions

All authors contributed equally to this work. They all read and approved the last version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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