Original Research Article

The Physicochemical Properties and Microbial Populations of Nicosulfuron Treated Soil in Yola, Adamawa State, Nigeria

ABSTRACT

This study was focused on evaluating the physicochemical properties and microbial population of nicosulfuron treated soils of Yola, Adamawa State, Nigeria. The study was carried out in both 2021 and 2022 in the Research Farm of the Department of Plant Science, Modibbo Adama University, Yola. The samples of the soil treated with the different concentrations of nicosulfuron were obtained at 0, 2, 4 and 6 Weeks after Treatment (WAT) at the depth between 0-12 cm. The physicochemical properties and the bacterial and fungal populations of the collected soil samples were determined using standard laboratory procedures. The results revealed that the soils treated with the 50, 100, 150 and 200 g/ha concentrations of nicosulfuron had a comparable values for physicochemical (except percentage moisture content, organic carbon and matter and total nitrogen) properties that include: pH, electrical conductivity, Calcium, magnesium and potassium ions, total exchangeable acidity, total exchangeable base, effective cation exchange capacity, percentage base saturation. On the basis of duration of application, however, the nicosulfuron had significant effect on the physicochemical properties with 6 WAT having the highest values for the physicochemical properties compared to other sampling durations. On the bacterial (except the fungal) population, the nicosulfuron also had a significant effect with the treated soils having the lowest populations of both bacteria and fungi. The concluded that the duration of application of nicosulfuron have significant effect on physicochemical properties of soil in Yola. On the bacterial and fungal populations of the soil, nicosulfuron also had significant effect.

Keywords: Nicosulfuron, Fungi, Bacteria, Soil physicochemical properties, Microbial populations

1.0 INTRODUCTION

Physicochemical properties is a general term used to refer to both the physical and chemical properties of soil. The physical properties of soil are those components of soil that relate to the size and arrangement of solid particles, and how the movement of liquids and gases through soils is affected by the particles. They include: the structure, pore space, bulk density, soil color, soil permeability, atterberg limits, particle density and consistence. These physical properties are very important in agricultural production and for sustainable use of soil. The amount and rate of water, oxygen and nutrient absorption by plants depend on the ability of the roots to absorb the soil solution as well as the ability of the soil to supply it to the roots. Soil properties such as low hydraulic conductivity can limit the free supply of water and oxygen to the roots and affect negatively to the agricultural yield [1]. The chemical properties on the other hand which include: inorganic matters, organic matter, organic carbon, pH, caution exchange capacity, soil nitrogen and solidity are of very important to soil fertility, plant growth and reproduction [1]. That is why it is very important to understand how chemical properties of soil interact to affect the soil's capacity to store and release nutrients and how soil chemistry can affect soil structure [2]. Soil microbial components are the microscopic forms of life that although, exist in colonies, but most of the times live as single cells. Most of these microbial components exist in topsoil, where food sources are plentiful, than in subsoil. They abound in the area that is very close to plant roots, called the rhizosphere, where sloughed-off cells and chemicals released by the roots provide ready food sources. Besides their primary role of organic matter decomposition, these soil microbes also help in: fixing nitrogen into the soil, thus in plant growth; detoxify toxic

chemicals; suppress the multiplication of disease organisms; and produce substances that could help in stimulating plant growth. They are also of direct beneficial to humans as some are the source of most antibiotics used in fighting diseases [3].

The introduction and use of herbicides in agricultural system has greatly contributed to the quest of improving crop yield so as to meet the ever increasing human population. This is because the use of the herbicides has effectively aid in controlling and checking the growth of weeds, which are the major competitors to crops for soil nutrients and water. However, some of these herbicides were reported to have significant effect on both physicochemical and microbial components of soil [4] and [5]. A significant effect of herbicides like glyphosate, triclopyr and fluroxypyr on soil physicochemical properties that include pH and soil nitrogen was reported by [6]. Similarly, a significant increase in electrical conductivity as well as exchangeable acidity and minerals like: Ca, Mg, Na, K, Cu and Zn [7], total nitrogen, organic matter and phosphorus content due to over application of glyphosate [8]. Some other herbicides on the other hand, were reported to have no significant effect on soil physicochemical properties [9]; [10]. On soil microbial component, herbicides such as paraquat, glyphosate, 2,4-D amine and atrazine were reported to have a deleterious effect [11]. Also, soils treated with the different concentrations of the above mentioned herbicides were found to be devoid of some fungal species found present in the control soil samples. Generally, the functions of these herbicides in soils dependent upon the soil physicochemical properties and the types and ability of the soil microbe present in the soil. This explain why the effect of nicosulfuron on the physicochemical properties and microbial component of soils in Yola, Adamawa State, Nigeria was determined as nicosulfuron containing herbicides are the commonly used in the area for the control of weeds in maize fields.

2.0 MATERIALS AND METHODS

2.1 Description of Study Area

The study was carried out at the Research Farm of the Modibbo Adama University (MAU), Yola, Adamawa State, Nigeria between 2021 and 2022 rainy seasons. The study area is located in the North Eastern part of Nigeria and lies between Latitude 9^0 21'00" and 9^0 21'30" N of the equator and between Longitude 12^0 29'00" E and 12^0 30'30" E of the Greenwich meridian. It shares boundaries with Taraba State in south and West, Gombe in its North West, Borno to the North and Cameroon Republic in its Eastern borders. The area is in northern Guinea Savannah vegetation zone of Nigeria; and has an annual average rainfall and temperature of about 278.6 mm and 31.5^0 C respectively. The peak of the area relative humidity (71 %) is often in the month of August and September.

2.2 Experimental Design

Randomized Complete Block Design (RCBD) which was replicated three times was used for the study. Each of the blocks was 1 x 1.5 m^2 in size; and had 0.5 and 1 m intra and inter block spaces.

2.3 Treatments

The study consisted of five (5) concentrations of nicosulfuron that include: 0, 50, 100, 150 and 200 g/ha.

2.4 Soil Treatment

The application of the above mentioned concentrations of nicosulfuron on soil was carried out once using a sixteen (16) litres knapsack sprayer. During the course of the treatment application,

polythene was used in covering blocks in order to prevent the drifting of treatments to unintended blocks.

2.5 Data Collection

2.5.1 Soil sample collection

The collection of the treated soil samples for determination of physicochemical properties and microbial counts were carried out at 0, 2, 4 and 6 weeks after treatment (WAT). It was collected at the depth of about 0-15 cm with the aid of soil auger and transferred into a well labelled black polythene bags and were mixed thoroughly.

2.5.2 Isolation, enumeration and identification of bacteria

About 10 g of the soil sample was taken and sieved properly so as to remove any foreign particles. About 100 ml of sterilized distilled water was added to it to make a dilution of 10^{-1}. Ten (10) ml of the aliquot was taken from this dilution and added to 90 ml of sterilized distilled water thereby making a dilution of 10^{-2}. In the same way, the soil sample was serially diluted (six fold series). One (1) ml of the aliquot was taken from dilution 10^{-5} and spread evenly with cotton swap on the prepared nutrient agar. This was allowed to set and then incubated at 37 ^{o}C for a period of 24 hours. The counting of the bacterial colony was done at the end of the incubation period.

The pure culture of the bacteria was obtained by sub-culturing each of the colonies observed. A sterile wire loop was used to pick a colony and streak on the surface of a freshly prepared nutrient agar. This was incubated at 37 ^{o}C in an inverted position for 24-48 hours. The obtained pure culture was stored in a refrigerator at 4 ^{o}C pending further analysis and identification [12].

The individual bacterial colonies was identified through the morphological and biochemical techniques using the taxonomy scheme of Bergey's Manual of Determinative Bacteriology. The cultural characterization of the bacterial colonies isolated was carried out by observing the colonies for color, shape, edge, elevation and surface appearance displayed on the nutrient agar whereas the biochemical tests such as catalase test, motility test and oxygen-relation, methyl Red tests, fermentation of sugars, Gram's reaction, coagulate test was carried out for the identification [13].

2.5.3 Isolation, enumeration and identification of fungi

The method of serial dilution was used for the isolation and enumeration of the fungi. The dilution of the soil sample was carried out in two replicates; and each replicate was diluted six times and labelled accordingly. About 50 g of the soil sample was added to 100 ml of 85 % sodium chloride (NaCl) solution and was thoroughly shaken to mix the solution. The solution then was diluted to a series of prepared vials containing 9 ml of 85 % NaCl solution. About 9 ml of the soil-NaCl solution was transferred to the first vial by using a pipette. Subsequently, another 9 ml of the solution from the first vial was transferred to the second vial and the steps continued until the last vial. About 0.1 ml of the solution in each vial was pipetted into the already prepared PDA plate that contain streptomycin (1 mg/100 ml). The solution was then spread on the plate by using a hockey stick and incubated at room temperature for seven (7) days. The colony of the fungi that appeared on the plate after the incubation period was counted and expressed as colony forming units per gram (cfu/g) by dividing the number of colonies formed by volume plated and multiplying it by dilution factor. Pure culture of each of the colonies was obtained through sub-culturing. The sub-culturing was done by picking each of the

colonies with sterile wire loop and culture on a freshly prepared PDA plate. This was again incubated for another seven days. The obtained pure culture was then used for identification [14].

The pure fungal isolates were identified and characterized based on the colony features (color, shape and size of hyphae); and microscopic appearances (nature of hyphae, and type of conidia) by using a compound microscope with digital camera using lactophenol cotton blue-stain slide mounted with a small portion of the mycelium.

2.6 Determination of Soil Physicochemical Properties

2.6.1 Soil moisture content

About 10 g of the soil sample was be taken. The weighed soil sample will then be oven dried at 105 °C for 24 hrs. Dry weight of the sample was taken till it showed its constant weight. The loss in weight corresponds to the amount of water present in the soil sample [15]. The formula below was used to calculate the moisture content.

$$\text{Moisture content (\%)} = \frac{\text{Loss in weight on dryin (g)}}{Initial\ sample\ weight\ (g)} \text{ x } 100$$

2.6.2 Soil pH

About 20 g of the air dried soil sample was measured and placed in a beaker and to this 50 ml of water was added. The mixture was stirred with glass rod for a period of about 10 minutes and allowed to stand for 30 minutes. The pH meter (ELMETRON, CPI-501, Poland) was calibrated using standard buffer solution of pH 4.0, 7.0 and 10.0. Then electrode of the pH meter was inserted into the supernatant solution and the pH reading was taken [15].

2.6.3 Organic carbon and organic matter

About 1 g of finely grounded soil sample was passed through 0.5 mm mesh sieve without loss was taken into 500 ml conical flask and to it, 10 ml of 1 N potassium dichromate and 20 ml concentrated H_2SO_4 was added with measuring cylinder. The contents was shaken for a minute and allowed to stand for 30 min. Then 200 ml of distilled water, 10 ml orthophosphoric acid and 1 ml diphenylamine indicator were added. The solution was titrated against 0.5 N ferrous ammonium sulfate till the colour changes from blue-violet to green. The results was calculated by the following formula:

Organic carbon % = $\frac{\text{N x (V1}-\text{V2)}}{S\ x\ 0.39}$ x mcf

Where:

N = Normality of ferrous ammonium sulfate (FAS)

V1 = Volume of 0.5 N FAS required to neutralize 10 ml of 1 N $K_2Cr_2O_7$, that is, blank reading (ml).

V2 = Volume of 0.5 N FAS needed for titration of soil sample (ml)

S = Weight of air-dry sample (g) 0.39 = 0.003 x 100 % x 1.31 (0.003 is the milli-equivalent weight of carbon (g). It is assumed that only 77% of the organic matter is oxidized and a fraction of 100/77 = 1.31

Organic matter (%) = Organic carbon (%) x 1.724

1.724 = average content of carbon in soil organic matter is equal to 58 %

2.6.4 Cation exchange capacity

About 1.3 g of soil was measured into centrifuge tube. About 11 ml of 1 N sodium acetate solution will be added into the centrifuge tube. It was then be shaken well and centrifuged. The supernatant liquid was decanted. About 11 ml of isopropyl alcohol was added into the centrifuge tube. The centrifuge tube was shaken well and centrifuged. The supernatant liquid was decanted. About 11 ml of 1 N ammonium acetate solution was added into the centrifuge tube. The centrifuge tube was shaken well and centrifuged. The supernatant liquid was then poured into the 100 ml flask. The solution in the 100 ml standard measuring flask will be made up to 100 ml. The flame photometer was calibrated with standard sodium solution. The prepared solution was then injected into the instrument and the reading was taken. CEC value was then determined by the formula introduced by [16].

$$\text{CEC, } cmol_{(+)}\ kg^{-1}\ \text{soil} = \frac{10 \times \text{Na concentration in meq/L}}{Mass\ of\ sample\ (g)}$$

2.6.5 Electrical conductivity

About 20 g of the air dried soil sample was into a beaker and to this 50 ml of water was added. The mixture was stirred with glass rod for 10 min and was allowed to stand for 30 minutes without any disturbances. The soil was allowed to settle down and the EC value was measured by inserting an electrical conductivity meter (SCHOTT handy lab LF11, Germany) in to the supernatant solution [15].

2.7 Data Analysis

All the data generated from the microbial count and physicochemical parameters were subjected to two-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS

version 25). Significant differences between means were separated using Duncan's Multiple Range Test (DMRT).

3.0 RESULTS AND DISCUSSION

The soil treated with the different concentrations of nicosulfuron showed no significant difference in their physicochemical (except %MC, OC, OM and %TN) properties. Although, the values for virtually all the physicochemical properties were comparable, but the soil treated with 50 g/ha concentration of nicosulfuron had the highest values for most of the physicochemical properties than soils treated with other concentrations of nicosulfuron and the untreated soil sample (Table 1). The non-significance of the values for almost all of the physicochemical properties of the soil of the study area treated with the different concentrations of nicosulfuron could be due to the pH content of the soil of the study area that is close or near to neutral as pH of soil determine to a great extent the function of herbicides in soil. This is because herbicides could only persist for some period of time or quickly degrade when outside of neutral or near a neutral pH (6.0 to 7.0) as reported by [17]. The sulfonylureas herbicides to which nicosulfuron belong are generally being affected by pH of soil. This explains the non-significance of values for majority of the physicochemical properties of soil of the study area. For herbicides from families other than the aforementioned, however, soil pH may have little influence on their persistence in soil, but not as the major and important factor [17]. Study by [9] similarly reported the non-significance of different concentrations of herbicides that include paraquat and glyphosate on physicochemical properties of soil like pH, organic carbon, cation exchange capacity and phosphorus. Also, the soil treated with atrazine resulted to a comparable values for physicochemical properties of soil that include pH, cation exchange capacity, total organic carbon, nitrates and even phosphorus [10].

The duration of application of the nicosulfuron was, however, observed to have significant effect on the soil physicochemical properties. The soil sampled at 6 WAT had the higher values for majority of the physicochemical properties than that sampled at 0, 2 and 4 WAT (Table 1). The lowest values for the soil physicochemical properties of soils sampled at the 0, 2 and 4 WAT than that at 6 WAT could be due to the effect of the herbicide that gradually reduce with the increase in period of application as was asserted by [18] thereby resulting to higher values for the physicochemical properties as observed in the 6 WAT. Contrary finding was reported by [19] who in their study observed the non-significance of duration of paraquat application on soil physicochemical properties. This could be that paraquat, unlike the nicosulfuron used in this study, persisted in the soil thus, leading to the non-significance in the effect of period of application on the soil physicochemical properties.

The effect of nicosulfuron concentrations on bacterial and fungal populations showed that nicosulfuron had significant effect on bacterial (except fungal) population. The nicosulfuron concentrations recorded the lowest bacterial (41.71, 49.31, 49.28 and 47.68 x 10^4) and fungal (198.13, 217.29, 205.62 and 187.77 x 10^4) populations than the control soil which had 55.40 and 217.85 x10^4 respectively (Table 2). The control soil had the highest bacterial population that was only significantly higher than the lowest recorded in soil treated with 50 g/ha of nicosulfuron (Table 2). The treated soil samples were lower in their microbial composition especially in bacterial component than the control soil sample due to the effect of the herbicide. This was in agreement with the finding of [20] who also recorded a reduction in the number of microbial organisms that include bacteria, fungi and actinomycetes in soil treated with different concentrations of nicosulfuron than that of the control soil sample. Similarly, [18] also recorded the same incidence when the soils they treated with the different concentrations of acetochlor,

atrazine and 2,4-Diethyl ester resulted to lower populations of bacteria, fungi and actinomycetes compared to that of weedy check and weed free soil samples.

Based on the duration of treatment application, the soil sampled at 0 WAT had the highest of both the bacterial and fungal populations compared with that sampled at 2, 4 and 6 WAT. This was an indication that the application of herbicides on soils does not result to immediate and obvious effect on the soil microbes until after some days. This explain why the bacterial and fungal populations were higher at 0 WAT than that due to other sampling periods.

4.0 CONCLUSION

Nicosulfuron have no significant effect on the physicochemical (except percentage of moisture content, organic carbon, organic matter and percentage of total nitrogen) properties of soil of Yola. Based on the duration of application, however, nicosulfuron had significant effect on the soil physicochemical properties. The effect of the herbicide on the soil physicochemical properties decreases with increase in duration of application. Also, the nicosulfuron significantly affect the bacterial (except fungal) populations of the soil of Yola.

Table 1: Effect of Nicosulfuron at Different Concentrations and Sampling Duration on Soil Physicochemical Properties

	Soil Physicochemical Properties													
Treatment	**pH**	**EC (ds/m)**	**%MC**	**OC (g/kg)**	**OM (g/kg)**	**%TN (cmol/kg)**	**Ca^{++} (cmol/kg)**	**Mg^{++} (cmol/kg)**	**K^{++} (cmol/kg)**	**Na^{++} (cmol/kg)**	**TEB**	**TEA**	**ECEC**	**PBS**
Concen. (g/ha)- C														
Con.	6.47^{a}	0.18^{a}	10.23^{ab}	10.46^{ab}	18.04^{ab}	0.11^{ab}	1.36^{a}	0.59^{a}	0.46^{a}	0.39^{a}	2.80^{a}	3.33^{a}	6.12^{a}	44.27^{a}
50	6.32^{a}	0.17^{a}	10.60^{a}	11.45^{a}	19.75^{a}	0.12^{a}	1.24^{a}	0.76^{a}	0.61^{a}	0.49^{a}	3.10^{a}	2.97^{a}	6.07^{a}	51.51^{a}
100	6.25^{a}	0.17^{a}	9.08^{b}	9.83^{b}	16.95^{b}	0.10^{b}	1.40^{a}	0.68^{a}	0.55^{a}	0.40^{a}	3.02^{a}	3.12^{a}	6.14^{a}	49.35^{a}
150	6.39^{a}	0.17^{a}	9.65^{ab}	10.15^{ab}	17.51^{ab}	0.11^{ab}	1.34^{a}	0.82^{a}	0.56^{a}	0.38^{a}	3.11^{a}	3.35^{a}	6.46^{a}	46.86^{a}
200	6.35^{a}	0.18^{a}	9.65^{ab}	10.64^{ab}	18.34^{ab}	0.11^{ab}	1.22^{a}	0.83^{a}	0.50^{a}	0.37^{a}	2.93^{a}	3.53^{a}	6.45^{a}	46.21^{a}
SE±	0.11	0.03	0.48	0.44	0.76	0.01	0.13	0.13	0.09	0.05	0.21	0.22	0.30	2.44
Sampling Time - ST														
0 WAT	5.68^{a}	0.18^{a}	9.77^{ab}	9.86^{b}	16.99^{b}	0.11^{ab}	1.02^{b}	0.42^{b}	0.75^{a}	0.47^{a}	2.66^{b}	3.21^{a}	5.88^{b}	47.58^{a}
2 WAT	6.59^{b}	0.19^{a}	9.68^{ab}	11.26^{a}	19.42^{a}	0.12^{a}	0.87^{b}	0.52^{b}	0.52^{b}	0.35^{ab}	2.26^{b}	3.22^{a}	5.49^{b}	40.35^{b}
4 WAT	6.59^{b}	0.17^{a}	9.30^{b}	9.93^{b}	17.12^{b}	0.10^{b}	1.65^{a}	1.04^{a}	0.34^{b}	0.33^{b}	3.36^{a}	3.37^{a}	6.73^{a}	49.87^{a}
6 WAT	6.55^{b}	0.16^{a}	10.62^{a}	10.99^{ab}	18.94^{ab}	0.11^{ab}	1.71^{a}	0.96^{a}	0.54^{ab}	0.48^{a}	3.68^{a}	3.22^{a}	6.90^{a}	52.78^{a}
SE±	0.09	0.02	0.43	0.39	0.68	0.00	0.12	0.12	0.08	0.05	0.18	0.20	0.27	2.18
Interaction														
C x ST	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means along the column under each treatment group with the same superscript letter(s) are not significant different at $p \leq 0.05$.

Key: Con= Control; %MC= Percentage moisture content; %TN= % Total nitrogen; TEB= Total Exchangeable Base; TEA= Total Exchangeable Acidity; ECEC= Effective Cation Exchange Capacity; PBS= Percentage Base Saturation; NS = Not significant; WAT = weeks after treatment; Concen. = Concentration

Table 2: Effect of Nicosulfuron and Sampling Duration on Soil Bacterial and Fungal Populations in Yola

Treatment	Microbial Organism	
	Bacteria ($x10^4$)	Fungi ($x10^4$)
Concentration (g/ha) - (A)		
50	41.71^b	198.13^a
100	49.31^{ab}	217.29^a
150	49.28^{ab}	205.62^a
200	47.68^{ab}	187.77^a
Control	55.40^a	217.85^a
SE±	3.68	32.71
Sampling Duration (Week) - (B)		
0	77.13^a	478.01^a
2	42.67^b	67.50^c
4	33.93^b	199.63^b
6	40.98^b	76.19^c
SE±	3.29	29.25
Interaction		
A x B	NS	NS

Means in the same column with the same letter(s) are not significantly different at $p \leq 0.05$.

Key: NS = No significant difference

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