



MINI REVIEW

A Review on the Effects of Residual Herbicides on Soil Microorganisms

¹Saleh B., ²Jibri S. A., ³Y. B. Kajidu and ⁴M. S. Gargo

¹Department of Agronomy, Faculty of Agriculture, Borno State University, Maiduguri, Nigeria

²Department of Agric Extension, Faculty of Agriculture, Borno State University, Maiduguri, Nigeria

³Department of Crop Production, Faculty of Agriculture, University of Maiduguri, Nigeria

⁴Department of Agronomy, Kano State University of Science and Technology Wudil, Kano, Nigeria

*Corresponding author: bukarsaleh2017@gmail.com, doi.org/10.55639/607.2333

ARTICLE INFO:

ABSTRACT

Keyword:

Soil,
Herbicides,
Microorganisms,
Dehydrogenase
Toxicity

Herbicides are chemical preparations intended to destroy plants, especially weeds, or to obstruct their growth. After field application, herbicides not only control targeted weeds, but may also have possible lingering effects in the soil, and provide significant exposure of microorganisms to the herbicides. Microorganisms play important role in maintaining soil structure and fertility. Results of different studies show that herbicide application resulted in the reduction of some microbial species, e.g., *Proteus spp.*, and *Actinomycetes spp.* *Bacillus spp.* and *Pseudomonas spp.* these are the microorganisms which were delicate to herbicidal treatment. Significant reductions in fungal activity in both artificial and natural environments as a result of herbicidal treatment were up to 4 times; thus, indicating a positive correlation between growth stoppage and application of the weedicide. Herbicides applied at higher doses are persistent in the soil and harm soil microorganisms. Herbicides such as Paraquat, glyphosate, and atrazine, reduce dehydrogenase activities of the soil. Most herbicides applied to the soil remain in the topmost layer of the soil where the higher concentration of soil microorganisms exist.

Corresponding author: Bukar Saleh, Email: bukarsaleh2017@gmail.com
Faculty of Agriculture, Borno State University, P.M.B. 1122, Maiduguri, Nigeria

INTRODUCTION

Herbicides are preparations designed to destroy plants, especially weeds usually prepared with organic chemicals (Stanley *et al.*, 2013). Weedicides get into the soil directly through treatment or indirectly through plants and water runoff. However, after application, herbicides can be (i) vaporize (volatilize); (ii) eroded through superficial overflow, (iii) seep into deep soil levels and groundwater, (iv) deactivated by flora, or (v) be adhered to the soil in which they are converted to microbiological degradation. A typical herbicide should be able to treat weeds and be degraded as fast as possible. Weedicides are specific regarding their lethal level; however, several combinations can lead to dangerous effect which is harmful to humans and the ecology (Michaelidou *et al.*, 2000). Herbicides can result in severe and inherent toxicity, which is dangerous for the ecology (Zain *et al.*, 2013). The longevity of various herbicides ranges from 9 to 116 years. Thus, the application of herbicides results in all living organisms being at risk of toxicity danger if there are no microorganisms in the soil (Rose *et al.*, 2016). Deleterious effects of residual herbicides in soils result in the;

1. Contamination of the soil with injurious elements with prolonged effects by these chemicals so, these becomes harmful to other living organisms, including soil microbes (Simon-Sylvestre and Fournier, 1979; Wardle and Parkinson, 1990).
2. Herbicides build up in the soil after continuous application, then these becomes a threat to flora and fauna, wild life and humans (Amakiri, 1982).
3. Herbicides are becoming threatening not only to flora but also to flora fauna. Thus, resulting in significant reduction

- in their beneficial activity (De-Lorenzo *et al.*, 2001).
4. Significantly affecting dehydrogenase activity and mycelia growth (Nada *et al.*, 2001).
5. High dose of weedicide application decreases the number of knots in symbiotic nitrogen-fixing bacteria, nitrogenase activity microorganisms, dry matter in plants, lysis of bacteroids, and reduction of ATP synthesis (Burul *et al.*, 2022; Milošević *et al.*, 2001).
6. Continuous application of these herbicides results in inhibition of natural processes (soil bacteria, fungi and actinomycetes whose activities influences the soil fertility) within the soil and significantly reduces their performance (Zain *et al.*, 2013).
7. Numerous studies also have indicated; that destruction of soil health with these chemicals depends on the longevity of the herbicides in the soils, the amount applied and the toxicity of the chemical; more so, most of these weedicides are prepared to stay longer enough to have the desired action on the weeds (Adomako and Akyeampong, 2016).
8. In addition, application of 2, 4 -D higher than 5mg/Kg showed inhibition on dehydrogenase activity (Rose, 2016). Herbicides such as paraquat had shown lasting negative effect on soil fungi from 87.2-6.4%. Most herbicides commonly in use inhibited growth of specific microorganisms though organic matter has not reduced (Adomako and Akyeampong, 2016). However, significant response of soil microbial activity to herbicide treatment and increased adaptation of

the microbial community to the stress caused by increase in concentration of the herbicides over weeks of treatment (Sebiomo *et al.*, 2011).

Effects of Herbicides on Microorganisms

Effects of microorganisms on herbicides, which deal with the metabolism and breakdown of herbicides into components that are typically less phytotoxic than the original compound, and effects of herbicides on microorganisms by direct or indirect action of the herbicide on the (growth and physiological processes of the soil) microflora (Young, 2002).

The primary and secondary groups of microorganisms are responsible for the breakdown and decomposition of herbicides after application to soil, these are induced by enzymes after some period of adaptation. Prolonged application of herbicides such as glyphosate minimized the presence of these microorganisms and thus increases the negative effect (Hart and Brookes, 1996).

The function of bacteria and other microbes in the soil

Bacteria are the smallest organisms (they are prokaryotic) e.g., *Pseudomonas* metabolise an acid type of chemical fertilizer, *Nitrobacter* turn nitrite into nitrate and *Clostridium* can grow in the absence of O₂.
- Actinomycetes: these are a type of bacteria that share some characteristics with fungi, responsible for spore formation and secondary metabolism production

- fungi: are important in the soil as a food source for other larger organisms and pathogens beneficial symbiotic relationship with plants and soil health

- Algae capable of performing N₂ fixation e. g (Cyanophyceae, Chlorophyceae, Bacillariaceae)

Importance of micro-organisms

1. Microorganisms enhance food flavour; an example of such is *Methylobacterium extroquens*

increases the production of furanone a group of molecules that gives strawberries their typical flavour.

2. Microorganisms' presence in the soil is a good sign that shows that soil is healthy and these are affected whenever there is a change in the soil ecology (Schouten *et al.*, 2000).
3. They can sense significant changes in soil structure both positive and negative, thus providing an early sign of soil improvement or an early warning of soil degradation.
4. Physical and chemical processes are not enough to fulfil the integrated soil processes without the presence of soil microorganisms (Carter *et al.*, 1999).
5. Microbes also are sensitive to ecological stress compared to higher organisms.
6. The presence of a lot of microorganisms is a good indicator of soil perfection or timely notice of soil dilapidation.
7. Soil microorganisms are important because they affect soil structure and add fertility. Soil Microorganisms are classified as bacteria, fungi, actinomycetes algae and protozoa
8. Mycorrhiza is root fungi from a dense network of this filament acting as an extension of plant roots, they facilitate the uptake of water and nutrients.

Dehydrogenase action is supposed to be a sign of total microorganisms' activity, because it takes place among the cells in all breathing microbial cells and is linked with microbial oxidation processes (Quilchano and Maranon, 2002; Stepniewska and Wolinska, 2005). It is a particular type of enzyme which plays an important part in the biological oxidation of soil organic matter by transporting protons and electrons from substrates to acceptors. Soil dehydrogenase activity is

considered to be a significant indicator for measuring the side effects of herbicide treatments on the soil microbial biomass (Nada *et al.*, 2001). In general, continuous application of these herbicides results in their residual effects which in turn affect both qualitative and quantitative presence and actions of the microbial population in the soil (Singh *et al.*, 2020).

Breakdown of herbicides by Microorganisms

Lynch (1983) and Radosevich *et al.* (1995) reported that herbicide-degrading microbes belong to bacteria and fungi: *Arthrobacter*, *Pseudomonas*, *Bacillus*, *Actinomycetes*, *Mycoplasma*, *Agrobacterium*, *Corynebacterium*, *Arthrobacter*, *Flavobacterium*, *Nocardia* and *Trichoderma*. The major microbes in the soil are algae, fungi, actinomycetes, and bacteria, for them to have means of survival majority of these microbes depend on the organic compound for their food supply but a few of them derive their food from inorganic compounds. Some herbicides are broken down by some of these microorganisms such as fungi and bacteria as a food source warm temperature, favourable pH levels, adequate soil moisture, oxygen and fertility are conditions that favour microbial growth. Adsorbed herbicides are more slowly degraded because they are less available to some microbes. All types of organic matter are used by these microbes, including organic herbicides. Some herbicides are easily degraded (easily utilized by the microorganisms), whereas others are persistent (Rana and Rana, 2016). Generally, herbicides affect soil microorganisms indirectly and may be a source of food for microorganisms (Cook and Hutter, 1981). Different studies were

conducted by researchers to determine the negative effects of higher doses of herbicides on soil microorganisms; these are presented as follows.

Effect of Application of Herbicide (Atrazine and Paraquat) on Soil Bacterial Population

From Stanley *et al.* (2013)'s research, where bacteria are recovered from herbicide-treated and untreated soils at various depths, Table 1 was taken. At both the 10 cm and 20 cm depths of the soil, the untreated (control) area exhibits a greater population of bacteria (6 population). By significantly reducing the number of bacteria to just 2 bacteria (*Bacillus cereus*, *Pseudomonas spp.*) at 10 cm of soil depth and 1 bacterium (*Bacillus cereus*) at 20 cm of soil depth after treating the soil with paraquat at the recommended rate, it was shown that these bacteria are sensitive to paraquat treatment. At the 10 cm soil layer, the number of bacteria was reduced by half when the amount of paraquat was raised by half, leaving only 2 bacteria. Following another application of the herbicide atrazine at the approved rate, the bacteria were significantly reduced to 3 bacteria at both the 10 cm and 20 cm depths of the soil. The considerable reduction of the microorganism by 3 bacteria at 10 cm and only 2 bacteria at 20 cm soil depth is further demonstrated by increasing the rate of atrazine by half. The bacteria that were sensitive to herbicide treatment might therefore be used as a reliable indicator of the biological value of soils, while those that were resilient may be further investigated for purifying reasons. The findings of Sebiomo *et al.* (2011), who discovered a strong response of soil microbial activity to herbicide application and greater adaption of the microbial community, are in contrast to this study.

Table 1: Bacteria isolated from control and herbicide treated soils in relation to depth

Soil treatment	Bacterial Isolates	
	10cm depth	20cm depth
Control	<i>Bacillus cereus</i> , <i>Pseudomonas</i> sp. <i>Actinomycetes</i> , <i>Bacillus subtilis</i> , <i>Proteus</i> spp. <i>Micrococcus</i> spp.	<i>Bacillus cereus</i> , <i>Pseudomonas</i> sp. <i>Actinomycetes</i> <i>Bacillus subtilis</i> , <i>Proteus</i> spp. <i>Micrococcus</i> spp.
G1	<i>Bacillus cereus</i> , <i>Pseudomonas</i> spp.	<i>Bacillus cereus</i> .
G2	<i>Bacillus cereus</i> , <i>Pseudomonas</i> spp. <i>Bacillus subtilis</i>	<i>Bacillus cereus</i> <i>Pseudomonas</i> spp.
M1	<i>Bacillus cereus</i> , <i>Pseudomonas</i> sp. <i>Bacillus subtilis</i>	<i>Bacillus cereus</i> , <i>Pseudomonas</i> spp. <i>Micrococcus</i> spp.
M2	<i>Bacillus cereus</i> <i>Pseudomonas</i> spp. <i>Micrococcus</i> spp.	<i>Bacillus cereus</i> <i>Pseudomonas</i> spp.

Source: Stanley *et al.* (2013)

G1: recommended rate of paraquat

G2: x0.5 recommended rate of paraquat

M1: recommended rate of atrazine

M2: x 0.5 recommended rate of atrazine

Effect of Herbicides on Microbiological Properties of Soil

Generally, microbes are indirectly affected by herbicides, disrupting the health of the soil, amplifying enzymatic activities, and increasing dose application results in the death of vulnerable microbes. It has been noticed that some types of microbes (first group) start to break down weedicides a few days after application. On the other hand, the second group of microorganisms, give rise to enzymes that induce and degrade the herbicides. During the period of adaptation, some microbes are sensitive to herbicide application, so these microbes are killed in the process of adaptation (Figure 1). The persistence of (19 years) of glyphosate reduces C biomass in soil, but

ammonification and nitrification are amplified compared with untreated soil. Studies by many authors (Lynch, 1983; Radosevich *et al.*, 1995;) where had similar findings that herbicide-degrading microbes belong to bacteria and fungi: *Arthrobacter*, *Pseudomonas*, *Bacillus*, *Actinomycetes*, *Mycoplasma*, *Agrobacterium*, *Corynebacterium*, *Arthrobacter*, *Flavobacterium*, *Nocardia* and *Trichoderma*. Generally, herbicides affect soil microorganisms indirectly. weedicides may be a source of food for microorganisms (Cook and Hutter, 1981), and they are capable of significantly affecting microbial development and reproduction. However, herbicides also affect the microbes physiologically by:

a) by changing their biosynthetic devices (a transformation in the amount of protein biosynthesis is shown on the ratio of extra and intracellular enzymes);

b) by changing their protein biosynthesis;

c) by affecting the cellular tissues (changes in transport and excretion processes);

d) by affecting plant hormones (transport of indole acetic acid, gibberellin synthesis and ethylene level);

e) high doses application may kill microorganisms

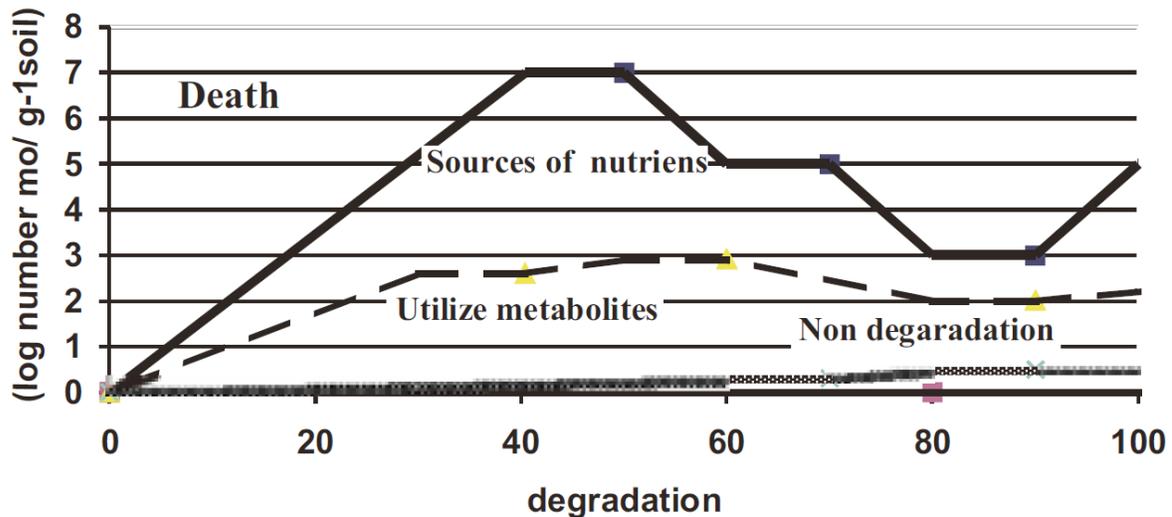


Figure 1: Effect of herbicides on soil microbiological population

Source: Nada *et al.* (2001)

Effect of four herbicides on microbial population, soil organic matter and dehydrogenase activity

After a period of six weeks, the effect of four herbicides (atrazine, primextra, paraquat and glyphosate) on soil bacterial population, soil biological material and enzymatic activity was evaluated. Soil specimens from cassava farms were applied with herbicides at factory-recommended rates. Soil enzymatic action was measured at a four-day sampling gap up to the 20th day. Bacterial, fungal and actinomycetes amounts were significantly reduced after application with herbicides when compared to the control (no treatment). Soil organic matter percentage was significantly reduced after the

soil was treated with the weedicide. Herbicide application resulted in a significant reduction in the hydrogenase activity of the treated soil when compared to the control soil samples. Obtained results indicated that when primeextra was applied to the soil, it had the lowest dehydrogenase activity of 16.09 $\mu\text{g (g-1min-1)}$ after the sixth week of application, while glyphosate application resulted in the highest enzymatic activity of 20.16 $\mu\text{g (g-1min-1)}$ when compared to other herbicides used for treatment, this finding is in support of Rana and Rana (2016) where they reported some microorganisms to have the ability to breakdown herbicides under favourable conditions. This study indicated a significant

reaction of soil microorganism's activity to herbicide treatment and increased adaptation of the microbial community to the stress as a result of an increase in the quantity of the herbicides over weeks of application thus this finding is in tandem with (Quilchano and

Maranon, 2002; Stepniewska and Wolinska, 2005) where they reported that dehydrogenase action is supposed to be a sign of total microorganisms activity which is reduced as a result of the herbicides applied.

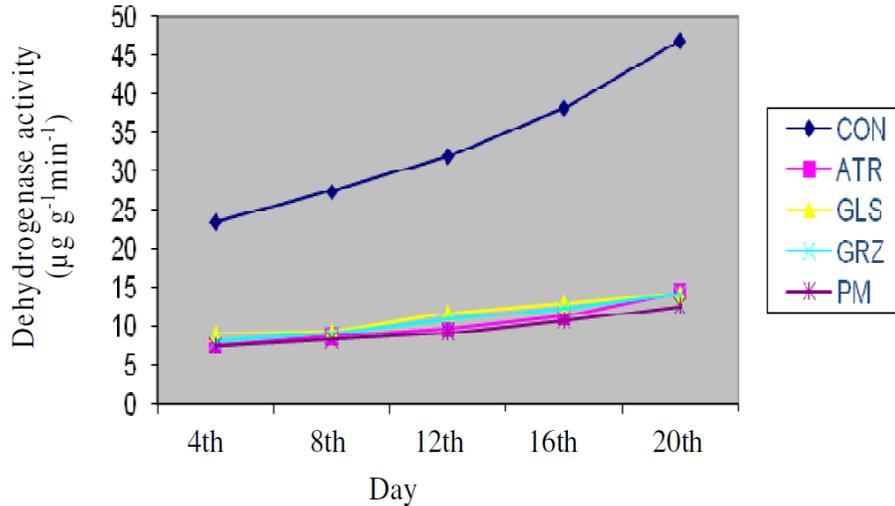


Figure 2: Effect of herbicides on soil bacterial populations

Source : Sebiomo *et al.* (2011).

CON = Control ;

ATR = atrazine treated soil;

GLS= glyphosate treated soils;

GRZ = paraquat treated soils;

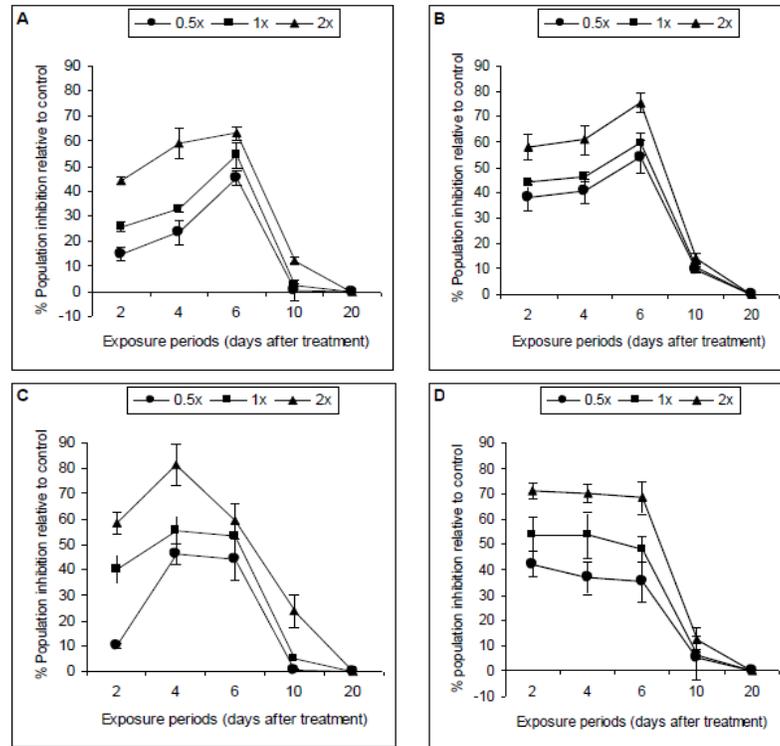
PM = primeextra treated soils.

For herbicide treatment, weeks of herbicide treatment and herbicide x week of treatment, P-value <0.001.

Effect of Selected Herbicides *In Vitro* and Soil on Growth and Development of Soil Fungi from Oil Palm Plantation

In-vitro application of weedicides; paraquat, glyphosate, glufosinate-ammonium and metsulfuron-methyl significantly reduced the fungal population from oil palm field soil.

When these herbicides were applied above recommended rates. The substantial upsurge of fungal growth inhibition was noticed with more herbicide concentration from 0.5× to 2× of their field recommended rates, showing a positive correspondence between stoppage in growth and action rates. Fungal growth inhibition was differential in their species due to the effects of herbicide treatments. *Mucor* sp. was much more affected negatively than *Aspergillus* sp. and *Penicillium* sp.



Source: Zain *et al.* (2013).

Figure 3: percentage population inhibition relative to control.

Key

- A: paraquat
- B: Glyphosate
- C: Glufosinate Ammonium
- D: metsulfuron methyl

Effect of Continuous Application of Herbicide on Soil and Environment

Research conducted in Southern Adamawa, Nigeria on the effects of continuous application of herbicide. Of the respondents, 63% of them revealed that there is a decline in micro-organic activities in the soil, and 80% of them indicated a reduction in water retention in soil due to the continuous application of herbicides. 87% responded impact of herbicide may endure for decades and affects soil conservation and lastly 85% indicated continuous application decrease soil organic matter. Field studies have indicated that weedicide is a sensitive substance in the soil. It accumulates harmful effects and stays

for decades, it reduces soil microorganisms, water-holding ability, and the ability of the soil to preserve nutrients. The action of living organisms is significantly affected in the soil. Field observation revealed that night workers and digging microorganisms have been damaged and vanished entirely due to the prolonged application of weedicides. This survey corresponds with the statement of (Simon-Sylvestre and Fournier, 1979; Wardle and Parkinson, 1990), whom they reported that herbicides are responsible for the pollution of the soil with harmful substances make it possible to exist that these chemicals may put

forth certain harmful effects on non-target organisms, including soil microorganisms.

Table 2: Effects of Herbicide on Soil

Effect Of Herbicide on Soil Effect	Effect category %		Percentage 100
	Negative	No effect	
Decline of micro-organic activities Soil degradation	63	37	100
Reduction of water retention in soil	82	18	100
Impact may endure for decades and affect soil conservation	80	20	100
Continuous application decreases organic matter	87	13	100
	85	15	100

Source: Daniel *et al.* (2013).

CONCLUSION

Microorganisms play important role in maintaining soil structure and fertility. Herbicides applied at higher dose are persistent in the soil and they have negative effect on soil microorganism. Herbicides such as Paraquat,

glyphosate, atrazine, reduce dehydrogenase activities of the soil. Most herbicides applied to the soil remain in the topmost layer of the soil where the higher concentration of soil microorganism exist.

REFERENCES

- Adomako M. O. and Akyeampong S. (2016). Effect of Some Commonly Used Herbicides on Soil Microbial Population *Journal of Environment and Earth Science* www.iiste.org ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) Vol.6, No.1, pp 30-38
- Amakiri M. A. (1982). Microbial Degradation of soil applied herbicides. *Nig. J. Microbiol.*, 2: 17-21.
- Buru F., Bari K., Lakić J. and Milanović-litre A. (2022). Herbicides effects on symbiotic nitrogen-fixing bacteria. *Journal of Central European Agriculture*, 23(1), p.89-102 <https://doi.org/10.5513/JCEA01/23.1.3320>
- Carter, M. R., Gregorich, E. G., Angers, D. A., Beare, M. H., Sparling, G. P., Wardle, D. A., and Voroney, R. P. (1999). Interpretation of microbial biomass measurements for soil quality assessment in humid temperate regions. *Canadian Journal of Soil Science* 79:507-520.
- Cook A. M. and Hutter R. (1981): s-Triazines as nitrogen sources for bacteria. *Journal of Agricultural and Food Chemistry*, 29, 1135—1143
- Daniel M. Duniya N. Idris G. Adams (2013). Effect of Continuous Application of Herbicide on Soil and Enviroment with Crop Protection Machinery in Southern Adamawa State. *International Refereed Journal of Engineering and Science (IRJES)* Volume 2, Issue 6, PP.04-09
- De-Lorenzo M. E., Scott G. I., Ross P. E. (2001). Toxicity of pesticides to aquatic microorganisms: a review. *Environ. Toxicol. Chem.*, 20: 84-98.
- Hart M. R. and Brookes P. C. (1996). Soil microbial biomass and mineralization of soil organic matter after 19 years of cumulative field applications of pesticides. *Soil Biol. Biochem.* Vol. 28, No. 12, 1641—1647.

- Lynch, J. M. (1983): Microorganisms and enzymes in the soil. In: *Soil biotechnology, Microbiological Factors in Crop Productivity*, Blackwell Sci. Publ., London, 185
- Michaelidou St. C., Piera P. and Nicolaou S. A. (2000). Evaluation of combination toxic effects and genotoxicity of pesticides for environmental protect and sustainability. Proceeding of the 1st European Conference on Pesticides and Related Organic Micropollutants in the Environment (T. Albanis ed.), Ioannina, Greece, 49—52.
- Nada A., Milošević N. and Mitar M. and Govedari C. A. (2001). Effect Of Herbicides On Microbiological properties Of Soil Proceedings for Natural Sciences, *Matica Srpska Novi Sad*, 102, 5—21.
- Quilchano C. and Maranon T. (2002). Dehydrogenase activity in Mediterranean forest Soils. *Biol. Fert. Soils*, 35: 102-107.
- Radosevich M. Traina S. J. Hao Y. I. and Touvinen O. H. (1995): Degradation and mineralisation atrazine by a soil bacterial isolate. *Applied and Environmental Microbiology*, 61, 297—302.
- Rana S. S. and Rana M. C. (2016). Principles and Practices of Weed Management. Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, 138 pages.
- Rose M. T., Cavagnaro T. R., Scanlan C. A., Rose T. J., Vancov T., Kimber S., Kennedy I. R., Kookana R. S. and Zwieten L. V. (2016). Impact of herbicides on soil biology and function. *Adv Agron* 136:133–220
- Schouten A. J., Bloem J., Didden W. A. M., Rutgers M., Siepel H., Posthuma L., and Breure, A. M. (2000). Development of a biological indicator for soil quality. *SETAC Globe* 30-32.
- Sebiomo V., Ogundero W. and Bankole S. A. (2011). Effect of four herbicides on microbial population, soil organic matter and dehydrogenase activity *African Journal of Biotechnology* Vol. 10(5), pp. 770-778.
- Simon-Sylvestre G. and Fournier J. C. (1979). Effects of pesticides on soil micro flora. *Adv. Agron.*, 31: 1-92.
- Singh M. K., Singh N. K., and Singh S. P. (2020). Impact of herbicides on soil microorganisms. *Plant response to soil pollution* https://doi.org/10.1007/978-981-15-4964-9_11_17911.1
- Stanley H. O., Maduiké E. M and Okerentugba P. O. (2013). Effect of herbicide (atrazine and paraquat) application on soil bacterial population *Sky Journal of Soil Science and Environmental Management* Vol. 2(9), pp. 101 - 105
- Stepniewska Z. and Wolinska A (2005). Soil dehydrogenase activity in the presence of chromium (III) and (VI). *Int. Agrophys.* 19: 79-83.
- Wardle D. A. and Parkinson D. (1990). Effects of three herbicides on soil microbial biomass and activity. *Plant Soil*, 122(1): 21-28.
- Young A. L. (2002). Agent Orange and Vietnam Revisited. *ESPR – Environ Sci & Pollut Res* 9 (3) 158–161
- Zain N. M., Rosli M., Mohamad B., Kamaruzaman-Sijam, Md., Mahbub M. and Yahya A. (2013). Effect of Selected Herbicides *In Vitro* and in Soil on Growth and Development of Soil Fungi from Oil Palm Plantation *International Journal Of Agriculture & Biology* 15–5–820–826.