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Effects of Organophosphate Herbicides on Biological Organisms in Soil Medium-A Mini Review

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Abstract

Herbicides are toxic agrochemicals, which have being used to fight against the existence of weeds in the agricultural farms and gardens. To some extent, these herbicides are rampantly used by farmers without considering the long or short term effects in soil medium. The aim of this paper was to provide a synopsis review of the effects of some organophosphate herbicides to soil biological community. It is evident that most of these herbicides may cause the reduction of sensitive populations of certain groups of biota in soil medium. This paper reported that the effect of organophosphate herbicides on soil biota is considerable. For example, Paraquat and round-up treated soils has been noted to cause decrease in heterotrophic aerobic bacterial count (HAB) and fungal population. It is believe that in cases where these herbicides are used to treat soils, they are considered harmful to nematode, earthworms and other biological organisms. They suppress the biodiversity of soil microbes, hinder the decomposition of soil organic matter and altered plant biomass. They also obstruct the biological activities of soil biota, photosynthetic, biosynthetic reaction, cell growth/divisions and molecular composition of soil biota. Understanding these effects is vital for variety of agricultural purposes including ensuring healthy soil and crop yield conditions, water sanitation, environmental quality and human health developments.

Keyword:

Herbicide; Soil; Biota

Introduction

Ecological soil environment is a multifunctional area that requires some knowledge about the various components of hazardous particles relevant to the proportions of the biological organisms' affected [1]. This is true particularly in achieving soil sustainability applicable to the composition of soil biological community [2]. The sustainable agriculture involves optimizing soil resources and maintaining the quality of environment and its natural resources [1]. The modern agricultural production, maintained that herbicide application should be on a regular practice primarily to minimize weeds problems in crop production [3]. Weeds and pests are known to affect the agricultural crops and cause yield reduction [4]. These weeds are described as any undesirable or troublesome plants, which grow freely where they are not wanted [4]. This agronomic situation demand for herbicides application to reduce or to some extent eliminates weeds for high crop yield performance. However, between and within the soil medium, are groups of biota such as bacteria, fungi, nematodes, earthworms, termites and protozoa, which may be affected by this application [5]. While, the vital roles played by these complex organisms in soil medium have been described as residue decomposition, nutrient recycling, soil structural stability and degradation of soil pollutants [2,6]. This entails the need to understand the effect as well as the relationship between soil biota and pesticide chemicals such as organophosphate herbicides. The essence of this can be related to the need to minimize agronomic problems such as increased application of herbicides without much concern to soil natural habitat, incorrect and indiscriminate application of herbicides as well as health condition of soil biota and other related organisms in soil medium [3].

Pesticides such as herbicides become incorporated in soil directly, during plant treatment, and indirectly, via water or residues of plant and animal origin [7]. After application, herbicides may evaporate (volatilize) and washed away through surface run-off or leached into deep soil strata and ground water [4]. They may be inactivated by plants or adsorbed in soil and become subjected to chemical degradation [4]. They are considered specific regarding their toxic level [8], and their application may lead to synergy and development of toxicity-hazardous to soil biota [8]. These effects are defined as acute and genetic, both of which are unsafe to soil microbial population in soil medium [9].

The interaction between herbicides and soil biota may be of practical significance because of possible inhibition in microbial activities contributing to soil fertility. Various studies have revealed that the herbicides can cause qualitative and quantitative change in enzyme activity [10-13]. For example, The Ontario College of Family Physicians released a literature review entitled "Pesticides Literature Review" [14]. The report informed people about the consequences and impact of pesticides to biological lives. Other effects include soil biological degradation, water contamination and various cancers in children such as Non-Hodgkin's Lymphoma and Leukemia [15]. The earliest report on herbicide usage dated 1878 was written when carbon bisulphide was used as a soil fumigant to kill plants (weeds) [16]. The report indicates that herbicide usage has not been developed until after 1896 when the phytotoxicity of copper sulphate was discovered. This development stimulated a search for other inorganic salts and acids suitable for selective weeds control leading to the test of iron, sulphates (including sulphuric acid) and arsenic on annual and perennial weeds

[16]. However, great literatures on the topic come from the 1940's, which remarkably increased in the 1950s upward. The military use of herbicides in tropical ecosystems as well as the achievements of yields increased in agriculture has provided a focus for this interest [17]. Therefore, this paper was intended to contribute with brief information about some effects of organophosphate herbicides to soil biological community. This is hoping to increase the public awareness of the effects of these groups of pesticide to both soil and biota in agricultural production.

The Effect of Organophosphate Herbicides on Soil Biota

Soil biota play a crucial role in carbon flow, nutrient cycling and litter decay, which in turn affect soil fertility and plant growth, and thus, occupying a unique position in biological cycles of terrestrial habitat [2,18-20]. Therefore, any change in the population and activity of these soil organisms may affect the entire soil system [21]. Organophosphate herbicides are among the major groups of pesticides, which include substances or cultured biological organism used to kill or suppress the growth of unwanted plants and vegetation [22,23]. They are considered extraneous to soil component pools expected to affect the catalytic efficiency, behavior of soil enzymes and biological activity of the soil-plant environment under different states [24,12]. A number of these pesticides have not only been introduced as pre or post-emergence weed killer but also depart unwanted residues in soils, which are ecologically harmful [25-28]. They also, create some adverse effects to the crops and ecological environment, while at the same time destroying the soil biota as non-target agent [29, 30]. These effects may reduce the performance of the important soil functions including soil quality and soil fertility developments [31,32]. This situation may create great risks to the entire ecological system in four major ways [33]: (a) changing their biosynthetic mechanism, (b) affecting protein synthesis, (c) affecting cellular membrane, and (d) affecting plant growth regulators. These ecological impacts can be re-examined in the following headings, further.

Effect on Biological Population

Biological population in soil medium can be grouped into micro, macro, and meso, biota the population of diverse organisms from bacteria, actinomycetes, fungi and algae to protozoa and nematodes, earthworms, termites, ants and the collembolan, mites and allies [1]. Microorganisms are heterogeneous group that include aerobes and anaerobes, heterotrophs and autotrophs or saprophytes, symbionts and parasites [5]. The application of organophosphate herbicides affects the size and composition of these organisms [3]. The outcome may cause the reduction of biodiversity of some groups of biota, affect the soil system, and also decrease the soil productivity functions [3,34]. The long term existence may also, persist to accumulate and creates a toxic level which finally becomes harmful to soil biological community [35,21]. Critically, some of these biological populations may have the ability to degrade herbicides and overcome the direct or immediate effects [36,27]. However, other populations have been noted to become seriously affected [12]. In this event, biological population may either be stimulated or suppressed due to factors such as mode and type of application, number of biota involved and soil environmental condition [37,38]. This also reduces the population size of the soil organisms, great biodiversity and biological cycles in soil medium [39,40].

Bacteria, Fungi and Allies

The effect of pesticides such as organophosphate herbicides on soil microbial community has been covered in some researches and studies [19,27,41-44]. The direct or indirect consequences can be related to both qualitative and quantitative changes of soil microbial populations [4,45] reported that the reduction of heterotrophic aerobic bacterial (HAB) count and fungal population was observed in paraquat and glyphosate treated soils. This reduction may be related to the fact that the application of the two organophosphate herbicides has affected the presence and existence of bacterial and fungal populations [46]. However, positive relationship may still exist with some organophosphates as noted in some studies [47,12]. This can be recorded in the works of Yu and Solomon who observed an increase in reproductive ability of bacteria following the application of butachlor [47]. This reproductive function was found to be less with the population of azotobacter when butachlor was applied [48]. The same compound was also noted to decrease fungal population as noted by Min and Xia. However, Mayeetreyee reported gradual increase in azotobacter, arthrobacter, heterotrophic aerobic bacteria, actinomycetes and fungal counts after dissimilar organophosphates herbicides were experimental in soils. This was largely related to the ability of these soil microbes to use the herbicides as energy source [49-51]. This means that the impact of organophosphate herbicides on these microbes was likely to be associated with the high application and concentration level in soil medium where bacterial and fungal populations exist. This situation explains bacteria and fungi with regard to the recovery system from the harmful effect of organophosphate herbicides as noted by Shukla and Mishra. They noted that unlike bacteria, most of the fungal population took times to recover from harmful effect caused by herbicides.

Generally, the admission of microbes to organophosphates such as paraquat in soil is limited due to the fact that it is easily bounded to clay mineral particles and organic matter [52]. Smith and Mayfield reported that paraquat could inhibit a great number of cellulolytic microflora, and cause injurious effects to symbiotic, anaerobic and nitrogen fixing bacteria. Wardle and Parkinson understood that a glyphosate may affect microbial population and their biodiversity in soil. Also, the rate of degradation can be affected by specific soil microbial community, although vary considerably in different soils [53]. At the same time, some soil microbial organisms used these herbicides as a source of carbon and energy, biogenous elements and decomposition abilities [3,51]. In another term, gram-positive and gram-negative bacteria were noted to use glyphosate after application as a source of phosphorus, carbon and nitrogen [54]. This ability provides a soil medium that supports an increase of the bacterial abundance, fungal counts and biomass [55-57]. These positives observations as with the exercise of organophosphate herbicides in agronomic practices does not mean that the use of pesticides should be encourage. This is because great numbers of soil biological population are affected directly or indirectly.

Soil microbial biomass on the other hand, plays one of the most important roles, which can be linked to diverse functional activities of microbes in soil [2,58,59]. The herbicides butachlor, pyrazosulfuron, paraquat and glyphosate were noted to cause a steady decline in the population of microbial biomass-carbon [45]. They hindered decomposition of soil organic matter and biodiversity of plant biomass [60-62]. De Lorenzo reported that the application of herbicides in the soil interferes with the vital processes of non-target soil

microorganisms such as respiration, photosynthesis and biosynthetic reaction as well as cell growth, division and molecular composition.

Effect on soil fauna-earthworms and allies

Soil fauna include the earthworms, termites and ants [2]. They played vital roles, which includes-shredding of plant litter, mineralization in the process of organic matter formation, producing casts that enhance soil nutrient availability and promoting of plant productivity [1,63]. They serve as feeders on decayed woods thereby indirectly increasing the aeration and drainage in soil, supporting the formation of humus and soil quality developments [6,2]. The herbicides effect on soil fauna has been noted to affect earthworms and related soil organisms [64,65]. Bon observed that earthworm (Eisenia fetida) has been affected by the application of glyposhate herbicide [66]. This indicates that glyphosate has a harmful effect on the viability of cocoons and biodiversity of earthworm population. For example, Gaupp-Berghausen reported significant decreased of the hatching rate of cocoons (17% to 43% for *Lumbricus terrestris* and 32% to 71% for *Aporrectodea caliginosa*) after glyphosate was used [63]. This contradict the observations made by Mohammed, Srivastava and Palta and Barman and Varshney; although these studies are related to organophosphate herbicides such as alachlor and fluchloralin in the experimental soil earthworms and nematodes [6,64,67]. According to Casabe, earthworms have chemoreceptors and sensory turbercles, which give them the ability to detect chemicals in the soil [68]. This ability helps them to move away from the affected areas to minimize the hazardous impact of the chemical ingredients. Despite this, Gbarakoro and Zabbey reported that Galumna spp., Scheloribates spp. and Crptophagus spp were susceptible to the synergistic mortality effect of both herbicides. This is also tallied with the work of Okiwelu who noted drastic reduced of mesofauna assemblages in the upper 10 cm of the soil after the application of atrazine [69].

Trivedi show that, both the increase and decrease effect occurred on nematode population when herbicides were used [70]. Gope and Borthakur observed an increase population of nematodes under a long term study of tea plantation using glyphosate, dalapon and simazine but noticed decrease with diuron [71-75]. On contrary, Swain studied the effect of bensulfuron-methyl, butachlor, quinclorac, thiobencarb, pretilachlor, pendimethalin, piperophos and 2,4-D in the field to control nematode Hirschmanniella mucronata in rice; they observed butachlor and pretilachlor to be the most toxic herbicides among others [76]. This study, tallied with the works of Panda and Sahu and Zhao with regards to earthworm and nematode population, respectively [77,78].

Conclusion

The indiscriminate use of herbicides has increasingly become a matter of environmental concern altering the soil fertility status and the population of biota. This is primarily because of their adverse effects on various components of biological organisms in soil medium. Although, the efficacy of herbicides in controlling the weeds is important, however, its residual impact should also be considered for environmental safety. The organophosphate herbicides are used either as pre-emergence or as post-emergence, and a high proportion reaches the soil and accumulates in various components of soil. This accumulation is believe to affect the numbers of biota, altered soil microbial biomass, decrease enzyme activities and biodiversity, which are good indicators of soil quality and soil function [2,79]. The review highlighted that some herbicides are hazardous to soil microbes while others are beneficial. Herbicides named butachlor, pyrazosulfuran, paraquat and glyphosate among others may alter the microbial populations with respect to different days after treatment. This effect may also leads to decline in biodiversity and microbial population development. However, the nutrient management practices such as application of organic manures and bioorganic fertilizers caused an increase in the abundance of soil microorganisms. This practice need to be incorporated in case the hazardous herbicides were decided to be used.

Recommendation

- There is a need to strengthen the scientific basis of modern agriculture, because herbicides may be useful if their persistence, bioaccumulation, and toxicity in agro-ecosystem are strictly controlled.
- Farmers should be trained in using different types of herbicides, their dose rate, time of application and also how and when to apply this agrochemicals.
- Government should create necessary awareness on toxic effect of herbicides in human body, their damages to ecosystem with respect to both short and long term effect.
- There is a need for the advent and use of cheaper, eco-friendly alternatives that result in increased crop production along with the judicious use of the known arsenal of agrochemicals as suggested by the integrated pest and nutrient management protocols.
- Seminars should be conducted, teaching farmers how to understand and follow the guidelines on herbicides in other to avoid soil contamination.
- We recommended that Agricultural Development Project (ADP) should organize training for rural farmers on application of herbicides and farmers should form associations so as to pull resources together, buy herbicides directly from the distributors in large quantity and disburse the herbicides among themselves to prevent been exploited especially the hike in price by the middle men.
- Governments should carry out research on effect of herbicides in all the agro-ecological zones, using the data to formulate recommendations for pesticide usage as part of a sustainable management of decomposition processes.
- Governments should draft out draft guidelines according to OECD standards for eco-toxicological tests under tropical condition.

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