

Soil Amendment for the Immobilization of Herbicide in Contaminated Soil Using Sawdust

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Abstract

Over the past years, the number of different herbicides has increased significantly. This has led to growing concern about the possible adverse effect on human health such as cancer, birth defects, reproductive problems, tumours, and damage of liver, kidney and neural organs. The environment is affected as abuse of herbicides this leads to contamination of soil, water, and air, thereby damaging the surrounding ecosystem and other living organisms necessary for maintaining ecological balance. The study investigates the effect of sawdust organic amendment on mobility of herbicides residues in contaminated soil, in which African Spinach (*Amaranthus hybridus*) is grown. Sawdust of Locust Beans tree (*Parkia biglobosa*) and Teak tree (*Tectonia grandis*) were used in a randomized complete block design. A composite sample of topsoil (110 kg), sawdust compost (10kg) were used, and 120kg of topsoil without sawdust compost was used as control. *Amaranthus hybridus* was planted in the potted mixtures and 120ml of herbicide (Glyphosate 41% SL) which was diluted with 5 litres of water and was applied to all treatment at equal rate after sowing. The Gas Chromatography Mass Spectroscopy (GCMS) analysis of the active ingredient in the glyphosate 41% SL indicates that the quantity of Isopropylamine was 34.093ppm. From the GCMS results, the highest mean of Isopropylamine (32.75ppm) was found in the control treatment prepared without saw dust amendment, as compared to other samples. However, no herbicide was detected in the vegetable raised in soils amended with compost made from *Parkia biglobosa* and *Tectona grandis* species. The study recommends reduced use of herbicides, especially on vegetables, by farmers.

Keywords: Herbicides, Glyphosate, Spinach, Uptake, Soil.

Introduction

The most widely recognized function of soil is its support for food production (Wiesmeier et al., 2019). It is the foundation for agriculture and the medium in which nearly all food-producing plants grow. In fact, it is estimated that 95% of our food is directly or indirectly produced on our soils (Food and Agriculture Organisation of the United Nations, 2012; Wiesmeier et al., 2019). Healthy soils supply the essential nutrients, water, oxygen and root support that our food-producing plants need to grow and flourish. Soils also serve as a buffer to protect delicate plant roots from drastic fluctuations in temperature (Food and Agriculture Organisation of the United Nations, 2012).

In terms of food availability, the world average per capita availability of food for direct human consumption improved to 2,770 kcal/person/day in 2005/2007. However, approximately 870 million people were still estimated to have been undernourished (in terms of dietary energy supply) in the period 2010–12. This figure represents 12.5 percent of the global population, or one in eight people. The vast majority of these, 852 million, live in developing countries, where the prevalence of undernourishment is now estimated at 14.9 percent of the population (FAO, 2012). The continuous increment in the demand for food around the world has necessitated the use of herbicides and other synthetic fertilizers, so as to meet up with the demand. Micronutrient deficiencies and over-usage of herbicide continue to affect around 2 billion people (FAO et al., 2012). More than 100 million children under the age of five are underweight, and therefore unable to realize their full socio-economic and human potential. The essentiality of Zn in the diet and its deficiency in humans was recognized in 1963. During the past 50 years, it has become apparent that deficiency of Zn in humans is prevalent with nearly 40% of the global population suffering from Zn malnutrition (Prasad, 2012). Childhood malnutrition is a cause of death for more than 2.5 million children every year (FAO et al., 2012).

In terms of the growth in agricultural production, to match the 1.1% growth in consumption, global production in 2050 would need to be approximately 60 percent higher than that of 2005/2007 (Alexandratos & Bruinsma, 2012). Fischer, et al. (2015) provides a comprehensive analysis of crop yield improvements and suggests that it would be prudent to have crop yield increases per annum of around 1.2 -1.3% which delivers around a 45% increase in stables over 2010 yields with a 10% increase in area cropped.

Pesticides are herbicides, insecticides and fungicides etc. applied to agricultural land to control pests such as weeds, insects and other organisms that disrupt crop production. Soil contamination can occur when pesticides persist and accumulate in soils, which can alter microbial processes, increase plant uptake of the chemical, and are toxic to soil organisms. The extent to which the pesticides and herbicides persist depends on the compound's unique chemistry, which affects sorption dynamics and resulting fate and transport in the soil environment (Sales, 2011). Pesticides can also accumulate in animals that eat contaminated pests and soil organisms. In addition, pesticides can be more harmful to beneficial insects, such as pollinators, and to natural enemies of pests (i.e. insects that prey on or parasitize pests) than they are to the target pests themselves (Gullan & Cranston, 2010). Persistence of pesticides in soils is dependent upon a number of chemical, climatic and edaphic factors (Božović et al., 2022). Highly chlorinated compounds which have low water solubility are the most persistent. Water soluble pesticides, which are easily biodegradable such as methyl carbamate and organophosphate insecticides are not persistent in the soil. The edaphic factors that influence persistence include soil type, temperature, moisture, cultivation, application and microbial ecology (Nirala et al., 2016; Božović et al., 2022).

Research indicate that most farmers use synthetic herbicide to control weeds in an effort to reduce or eliminate yield losses and preserve high product quality (Kughur, 2012). Chemical herbicides have contributed to the protection of crop, human, and animal health for over a half century. However, management of herbicides in developing countries is often inadequate due to lack of available resources (Özkara et al., 2016). This is particularly true for countries where regulations are not strictly implemented and farmers' knowledge of safe handling is often inadequate (Baudoux, 2004; Özkara et al., 2016). Many African countries such as Nigeria suffer from weak import controls, lack of training on appropriate herbicide use, inappropriate donations and aggressive sales practices, poor storage and stock management, pressure to stockpile for unforeseen emergencies, and a lack of safe destruction technologies (Ojo, 2016). Though a good number of farmers are disposed to the use of herbicides, many are unaware of herbicide types, level of poisoning, safety precautions and potential hazards on health and environment (Yassin et al., 2002; Muhammadu et al., 2020).

It was also observed that lack of knowledge of the use and the effect of these herbicide among small and large scale farmers has resulted in their misuse and consequently their accumulation in soil. It was also reported that 75.8% of farmers know that herbicide could harm the environment and 84.2% of farmers know that nausea, headache and vomiting are signs of herbicide poisoning (Uddin et al. 2015). Hence, the accumulation of herbicides in soil may adversely affect humans and other species that depend on vegetables as food. Thus, the need to study and know more about the proceedings.

Over the past years, the amount and number of different herbicides have increased significantly. This have led to growing concern about the possible adverse effect on human health such as cancer, birth defects, reproductive problems, tumours, and damage of liver, kidney and neural organs (Bernardes et al., 2015). Also, the environment is affected as abuse of herbicides could lead to contamination of soil, water, and air thereby damaging the surrounding ecosystem and other living organisms necessary for maintaining ecological balance, for example insects, birds, worms, fish, etc. (Wongwichit et al., 2012).

Many researches have been done to ascertain the efficacy of sawdust in amending soils with pesticide residues while growing vegetables, but no study has been done on sawdust of the tree species used in this study while growing *Amaranthus hybridus*. To this effect, this study seeks to study the effect of sawdust organic amendment on mobility of herbicides residues in contaminated soil growing an *Amaranthus* specie (African Spinach). This was done using sawdust of the following tree species: *Parkia biglobosa* and *Tectonia grandis*.

Materials and Methods

Description of Experimental Site

The experiment was carried out in the year 2020 at the Federal College of Forest Resources Management, Gongolong, Jere Local Government Area of Borno State Maiduguri, under screen house conditions. The area is located between latitude 11°04'59.99" North and

latitude 13008'60.00" East, with an annual rainfall of about 300-500mm and an average daily temperature ranging from 22-35°C, with a mean daily maximum temperature exceeding 40°C between March and June before the rainy season begins in July and September.

Treatment of Wood Samples (Composting)

Air, carbon materials (sawdust in this case), green grass (nitrogen source), and moisture were blended and put into bags open with small holes to allow air passage and frequent mixing (Chen et al., 2011). The sawdust samples were combined in this manner for six weeks before being applied to the soil samples.

Collection of Soil for Potting Mixture

Topsoil (0 – 15cm) were collected from the farm site at Gongolong. The soil was sieved to remove plant roots, as adapted from Awokunmi (2017).

Potting Mixture

According to the adaptation of the method prescribed by Beesley et al. (2014), 110 kg of topsoil and 10kg of sawdust compost of 3 different tree species were separately mixed using shovel and hoe for each treatment, and control sample, without sawdust compost making six treatments.

The treatments are:

- a. 10kg of sawdust compost of *Parkia biglobosa* tree and 110kg of topsoil were mixed
- b. 10kg of sawdust compost of *Tectonia grandis* tree and 110kg of topsoil were thoroughly mixed.
- c. 120kg of topsoil without sawdust compost as control.

Potting Experiment

Bucket size poly pot was used for the potting mixture where each sample in the treatment was filled with 20kg of the mixture, making 3 samples in each treatment.

Experimental Design

The experimental design used for this research was randomized complete block design. It is a design in which experimental material are divided into blocks of homogenous experimental units. Experimental unit has same characteristics and each block contained a complete set of treatment which is assigned at random to the experimental unit.

Sowing

The seed of *Amaranthus hybridus* was purchased from the local market at Gongolong, and used for the experiment. The seed was placed on the filled pot and covered with soil at shallow depth, and water it immediately after planting, the sowing was done on 03-09-2020

and germinated 07-09-2020, and watering were ongoing at the interval of 2 days for 6 weeks.

Herbicide Application

Mixture of Glyphosate water and soil was modified from many kinds of methods reported by Grey et al. (2002) and Ouyang et al. (2004). 120ml of (Glyphosate 41% SL) herbicide was diluted with 5 litres of water and was applied to all treatment at equal rate after sowing.

Harvest

Two plant stands of grown *Amaranthus hybridus* from each sample was harvested six weeks after sowing washed, shade drying and grounding to powder before taking it for gas chromatography analysis at Multi-User Science Research Laboratory ABU, Zaria, Nigeria.

Analysis of Topsoil and Sawdust Compost before Amendment

Samples of topsoil and sawdust compost of five different trees species was subjected to laboratory analysis to determine the following, PH, total nitrogen, organic carbon, organic matter, total phosphorus and total potassium in them. The samples were analysed at Soil and Water Management Laboratory Institute for Agricultural Research (A.B.U. Zaria).

Determination of Herbicides Residue in the *Amaranthus hybridus* through Gas Chromatography

Gas chromatographic (GC) methods are suitable for the separation and quantitative determination of compounds which are volatile or semi-volatile and thermally stable at the temperature of the measurement. It is thus used to separate and detect small molecular weight compounds in the gas phase. The sample is either a gas or a liquid. Gas chromatography was employed for the determination of the herbicides residues in the *Amaranthus hybridus*.

Analytical Procedure

Soil extracts were analysed by a Hewlett Packard Shimadzu model HPLC equipped with degasser and Spectrophotometric UV detector. A reverse-phase column with isocratic 4:1 methanol/H₂O mobile phase was used. A 25 cm × 4.6 mm i.d. Adsorbosphere C18 column, a flow rate of 0.5 ml/ min, and a detector wavelength of 290 nm were determined to be optimum for the analysis. A 20 µL injection volume was used. The mobile phase and the standard solutions were prepared from filtered HPLC grade solvents. Glyphosate dissipation curves in soil samples were fitted to first-order kinetics ($C = C_i e^{-kt}$) and half-lives ($t_{1/2}$) calculated.

Results and Discussion

Analysis of Topsoil and Sawdust Compost before Amendment

Samples of topsoil and sawdust compost of two different trees species were subjected to laboratory analysis to determine the following chemical composition, pH, total nitrogen, organic carbon, organic matter, total phosphorus, and total potassium in them. The samples were analysed at Soil and Water Management Laboratory Institute for Agricultural Research (A.B.U. Zaria). The results obtained are shown in Table 1 below. Top soil without sawdust compost as control is found to have a PH of 7.8, total nitrogen (0.06 kg¹) organic carbon (6.50g. kg¹), organic matter (112.80g kg¹), total phosphorus (0.19%) and total potassium (0.06%).

Table 1: Analysis of top soil

	P.H	Total Nitrogen	Organic Carbon		Organic Matter		Total Phosphorus		Total Potassium	
			(%)	(g.kg ⁻¹)	(%)	(g.kg ⁻¹)	(%)P	(P ₂ O ₅ %)	(%)k	%k ₂ o
Topsoil	7.8	0.06	0.65	6.50	11.28	112.8	0.19	0.43	0.06	0.07

Source: Field Survey 2021.

Parkia biglobosa tree is found to have a pH (8.3), total nitrogen (0.84g.kg⁻¹), organic carbon (92.60g.kg⁻¹), organic matter (159.60g.kg⁻¹), total phosphorus (0.27%) and total potassium (0.15%), *Tectona grandis* tree is found to have a pH (7.9), total nitrogen (0.76g.kg⁻¹), organic carbon (83.80g.kg⁻¹), organic matter (144.50g.kg⁻¹), total phosphorus (0.24%) and total potassium (0.18%). A research close to this was carried out by Horisawa et al. (1999), who studied the physical and chemical properties of three sawdust species (*Abiessachaliensis* masters, *Larix kaempferi* and *Picea ezonensis*) and soil. The total nitrogen, organic and carbon content results are similar to the result of this study, other parameters from this study are not understudied by Horisawa et al. (1999). The mixing procedure was however, done as adapted from Beesley et al. (2014).

Table 2: Analysis of sawdust compost before amendment

Tree Species	P.H	Total Nitrogen	Organic Carbon		Organic Matter		Total Phosphorus		Total Potassium	
			(%)	(g.kg ⁻¹)	(%)	(g.kg ⁻¹)	(%)P	(P ₂ O ₅ %)	(%)k	%k ₂ o
<i>Pakia biglobosa</i>	8.3	0.84	9.26	92.60	15.96	159.60	0.27	0.62	0.15	0.18
<i>Tectona grandis</i>	7.9	0.76	8.38	83.80	14.45	144.50	0.24	0.55	0.18	0.22

Source: Field Survey 2021.

GC-MS Analysis of the Active Ingredient in Glyphosate 41% SL

GC-MS was carried out on glyphosate 41% SL to estimate the quantity of its active ingredients in part per million (PPM). The active ingredient in the glyphosate 41% SL was found to be Isopropylamine salt and it is soluble in water. The GC-MS analysis of the active ingredient in the glyphosate 41% SL indicated that the quantity of Isopropylamine was 34.093 PPM, this is in conformity to what was obtained by Satchivi et al. (2000), who understudied the glyphosate isopropylamine salt content of glyphosate.

GC-MS of Amended Soil and Planted Amaranthus Samples

Gas Chromatography and Mass Spectroscopy (GC-MS) of Glyphosate 41% SL herbicide solution was carried out at the MULTI-USER Science Research Laboratory, Ahmadu Bello University, Zaria, in order to determine the uptake or the rate of immobilization of active ingredients (Isopropyl Amin) in both amended soil and in planted Amaranthus samples A-E respectively. The control for both the contaminated soil and the amended soil were also analyzed. The GC-MS of both amended soil and planted Amaranthus samples (A-E) were analyzed. The mean concentrations of Isopropylamine contained in soil samples amended with saw dust compost derived from various tree species is shown in Table 3.

Table 3: Concentration of Isopropylamine in contained soil samples

	Tectonia	Parkia	Control
Mean (ppm)	10.43	12.97	32.75

Source: Field survey, 2021

It can be seen from table 4 that the highest mean Isopropylamine (32.75ppm) was found in the control treatment without saw dust amendment. This is followed by the soil treated with Parkia saw dust with mean Isopropylamine value of 12.97ppm. Mendes et al. (2018) also observed significant reduction in the soil herbicide content, which involved the use of biochar as amendment on herbicide-contaminated soil.

Concentration of Glyphosate in Amaranthus Spp in Soil Amended with Various Saw Dust Compost

The mean values of Isopropylamine in Amaranthus spp raised in soils amended with compost derived from various tree species is shown in Table 4.

Table 4: Mean concentration of Glyphosate in *Amaranthus* spp in soil amended with various saw dust compost.

S/N	Plant species		
	Parkia	Tectona	Control
1	ND	ND	22.56

Source: Field survey, 2021

No herbicide content was detected in the vegetable raised on soils amended with compost made from *Parkia* and *Tectona* species. This is in conformity with the study of Mendes et al. (2018). As permitted for human food consumption, isopropylamine concentration of 250 parts per million and below is safe for consumption (FDA, 2013). Therefore, it can be inferred that the grown *Amaranthus* are safe for consumption.

Comparison of Herbicide Concentration in the Compost Amended Soils and *Amaranthus*

Table 5: Concentration of herbicides in compost amended soils and *Amaranthus*

Compost Amendment	Herbicide in Soil (ppm)	Herbicide in vegetable (ppm)
Tectona	12.96	ND
Parkia	10.43	ND

Source: Field survey, 2021.

The result obtained from table 6 show that no concentration of herbicide was detected in *Tectonia* and *Pakia*.

Conclusion

It was found that the sawdust compost in the soil samples plays significant roles in eradicating the content of herbicide in the grown *Amaranthus hybridus*. Thus, Gas Chromatography and Mass Spectroscopy (GC-MS) was employed to gather useful information on the chemical composition of Glyphosate herbicide solution and this was found to be Isopropylamine. GC-MS was also used to analyse the isopropylamine content of the compost-amended soil samples, as well as the *Amaranthus* grown in them. No herbicide was detected in the vegetable raised in soils amended with compost made from the two samples of *Parkia biglobosa* and *Tectona grandis* species. Lastly, as permitted for human food consumption, isopropylamine concentration of 250 parts per million and below is safe for consumption (Food and Drug Administration-FDA, 2013). Therefore, it can be inferred that the grown *Amaranthus hybridus* are safe for consumption.

Recommendations

Herbicides are often used at a rate more than the recommended dose for control of weeds and this leads to their build-up in soil and subsequent uptake among plants. To this effect, this study recommends:

1. optimized use of herbicides, especially on vegetables, by farmers. It is also strongly recommended that the state government and NGOs initiate special educational programs and the implementation of personal protective measures; such approaches are necessary to decrease the harmful effects of herbicide use on agricultural produce consumers.
2. for future research, it will be of immense use to intensify studies on the human and environmental effects of herbicides. Data on the occurrence of herbicide-related sickness among defined populations in developing countries are scanty. For example, there is need for inferential information on the domain of herbicide to illustrate situations in which people are undergoing life-long exposure and the effect of such. Also, a comparative study of other species of sawdust is of high importance.

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