Effect of mulch on glyphosate mobility in soil column

Mardiana-Jansar K1, Nurul Wadhihah Mazlan1, Zainol Maznah2 and Ishak MS1

1 Department of Earth Sciences and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia.
2 Malaysian Palm Oil Board (MPOB), No. 6 Persiaran Institusi, Bandar Baru Bangi 43000 Kajang, Selangor, Malaysia.

*Corresponding E-mail: mardiana@ukm.edu.my

Abstract. Glyphosate is a broad-spectrum herbicide that often used in controlling weed growth in oil palm plantation. Glyphosate has a high polarity and solubility in water and is quickly absorbed by soil particles. Oil palm waste such as oil palm trunks (OPTs) and empty fruit bunches (EFBs) and the use of glyphosate in agricultural land can contribute to environmental pollution. Apart from the commercial mulch that often used in nurseries, mulch from OPT and EFB can be used to absorb glyphosate to prevent weed growth. The glyphosate concentration of soil and water samples was determined using High Performance Liquid Chromatography (HPLC). Two doses of glyphosate were used which are 5.5 mL/L (2255 mg a.i/L) and 11 mL/L (4510 mg a.i/L). Two water volumes are used which are 250 ml and 500 ml. Glyphosate residual concentration values was high in Serdang soil series at layer three while in Selangor soil series at layer one. The highest concentrations of glyphosate residues were 32.57 mg/L and 34.42 mg/L at Serdang and Selangor soil series respectively. Samples of soil in the mulch of EFB and OPT show low concentrations of glyphosate residue compared to commercial and non-mulching column. Results show that EFB and OPT indicate low residual concentration values at each layer in the soil column for both doses.

Keywords: Serdang series, Selangor series, oil palm trunks, empty fruit bunches

Track Name: Advanced Technology and Renewable Energy

1. Introduction
Malaysia is the world's second largest producer of palm oil after Indonesia. Currently, the acreage of oil palm plantations in Malaysia has increased from 5.74 million hectares in 2016 to 5.81 million hectares in 2017 [1]. Based on this increment, biomass production from oil palm processing will indirectly increase. Oil palm processing activities in the factory will produce oil palm waste which is empty fruit bunches (EFB) while oil palm trunks (OPT) are obtained from the process of replanting oil palm after 15-20 years of planting. Oil palm stems have a content of lignocellulose which serves to absorb water molecules in moist areas under hygroscopic conditions. Empty fruit bunches are also a lignocellulose material containing 25% lignin, 50% cellulose and 25% hemicellulose in the cell wall [2].
According to Sanagi [3], the use of palm oil biomass-based materials to remove environmental pollutants (effluents) is a solution to the sustainability of sustainable development. The preparation of adsorbents or mulches from empty fruit bunches and oil palm stems is able to remove heavy metal ions and organic pollutants that exist in the environment. The use of mulch on the soil is among the practices performed by farmers to retain moisture and prevent evaporation from occurring on the soil surface [4]. The study conducted by Mohamad et al. [5] showed that weed growth in oil palm plantations is able to disrupt the oil palm growth process and reduce oil palm productivity if not controlled systematically.

Glyphosate, a broad-spectrum herbicide, is often used by farmers to control the growth of weeds in oil palm plantation. Glyphosate can be applied directly to the soil surface, released from plant roots or from decomposed plant tissues, as well as involving a transport retention (adsorption-adsorption) process [6]. Therefore, this study was conducted to study the best mulch for adsorption of glyphosate on agricultural soil and reduce weed growth in oil palm plantations. This is because the use of herbicides in uncontrolled doses is one of the unsustainable environmental management and can contaminate groundwater resources.

2. Materials and Method

The sampling location was at the Faculty of Agriculture, Universiti Putra Malaysia (2° 59' 00.0" N, 101° 44' 05.7" E) for Serdang soil series and the Malaysian Oil Palm Board (2° 58' 04.2" N 101° 44' 55.0" E) for Selangor soil series. A series of concentrations of glyphosate standard solutions in the concentration ranges from 0.005 to 0.05 µg/mL were prepared for glyphosate analysis. Glyphosate herbicides was prepared at 2 different concentrations, 11 mL/L (double the recommended dose) and 5.5 mL/L (recommended dose).

2.1 Soil column preparation

30 cm soil columns were used and arranged vertically at the Greenhouse, Plant House Laboratory, Universiti Kebangsaan Malaysia (UKM). A plastic funnel and water collector cup was placed at the bottom of each soil column. A total of 48 soil columns were used according to different pesticide concentrations, mulch and watering volume. Three types of mulch were used in this study (Figure 1). The empty fruit bunch and oil palm trunk waste, the samples should be completely dry before the analysis is performed. The mulch was cut to equalize the size of the mulch for each column. Three replications were prepared at each herbicide concentration, mulch and total watering volume. Each soil column was sprayed with 10 mL of pesticide at each concentration and sprayed on the first day only. After three hours of spraying, watering simulations were performed with 250 mL and 500 mL total volume of water. For water sampling, water was taken on the first day after spraying. A total of 10 mL of collected leachate was placed in a centrifuge tube (50 mL) according to pesticide concentration, mulch and water volume for pesticide analysis in the laboratory. For soil sampling, each soil layer was taken for extraction. The soil column was cut at three different depths (27 cm, 18 cm and 9 cm) and placed in a centrifuge tube (50 mL). A total of 5g of soil was taken for each different depth.

Figure 1. Mulch; a) oil palm trunk (OPT), b) commercial mulch (K) and c) empty fruit bunch (EFB).
2.2 Glyphosate extraction method for soil and water samples

5 g of soil sample was placed in a 50 mL centrifuge tube and extracted by adding 10 mL of 0.6 M KOH and shaken using an orbital shaker for 30 min. The sample was then put into a centrifuge machine at 3500 rpm for 30 min. Only 5 mL of solution was taken for analysis. For water samples, the sample does not need to be extracted. Borate buffer solution was prepared by dissolving 1.9 g of analytical reagent disodium tetraborate decahydrate (Merck) in 100 mL of deionised water. 50 mg of fluorenylmethyloxycarbonyl chloride (FMOC-Cl) (97%, Aldrich) was dissolved in 50 mL of acetonitrile to produce a solution of FMOC-Cl reagent. Every 5 mL of solution sample extracted from the soil sample and 10 mL of water sample were placed in each 15 mL glass vial for extraction. Each sample was mixed with 0.5 mL of borate buffer solution and 0.5 mL of FMOC-Cl solution. Samples were stirred using a magnetic stirrer for 15 minutes and left at room temperature for one hour for reaction. A total of 2 mL of diethyl ether solvent was added to clean the excess FMOC-Cl reagent and a separate water phase was taken and filtered with a 0.2 µm filter to be injected directly into the HPLC (Table 1).

Table 1. HPLC condition for glyphosate analysis.

| Column : | Zorbax Eclipse Plus C18 |
|------------------|--------------------------|
| Column temperature : | 40 ºC |
| Flow rate: | 0.5 mL/min |
| Flow period: | 15.0 min |
| Detector : | Fluorescent detector |
| Excitation wavelength : | -260 nm |
| Emission wavelength : | -310 nm |
| Injector (volume) : | Automatic (50ul) |
| Mobile phase : | A Phosphorus borate buffer solution (45%) |
| | B Acetonitrile (55%) |

3. Results and Discussion

3.1 Glyphosate residue in soil column

A slow decrease of glyphosate concentration occurred in soil column from layer 1 to layer 3 for dose concentrations of 11 ml/l and 5.5 ml/l for Serdang and Selangor soil series respectively. This happened because the simulation of watering that caused the glyphosate dissolved. Referring to Figure 2, the soil column without mulch at the top of soil column (B) recorded the highest average of glyphosate concentration in layer 3 which was 21.48 mg/L when a volume of 250 mL water was poured on Serdang soil series. The absence of mulch on top of the soil column caused the glyphosate in first layer to be less adsorbed and moved to third layer along with the water. This result was supported by Aslam et al. [7] who stated that mulch influenced the presence of residues in the soil through interception and retention processes as a result of evaporation, discharge and runoff.
Figure 2. Mean concentration of glyphosate residual at 250ml watering volume for Serdang series soil.

Based on Figure 3, the concentration of glyphosate residue for Selangor soil series on EFB and OPT showed low residue values of 15.26 mg/L and 15.82 mg/L respectively in layer 1 compared to commercial mulch (K) and column without mulch (B) for concentration dose 11 mL/L. The high carbon and nitrogen content as well as the presence of polymers such as lignin and cellulose in empty fruit bunch and oil palm trunk would act as a natural barrier against the decomposition process [8]. The presence of high organic matter that caused higher adsorption capacity in the Selangor series soil (Table 2) also prevents the movement of glyphosate. This result was supported by Duke et al. [6] and Mardiana-Jansar [9] who stated that glyphosate is strongly bound to soil particles and has a low desorption capacity, only a small amount of glyphosate was found on the soil surface for microorganism activity, uptake by plants and interaction between metals in the soil.

Figure 3. Mean concentration of glyphosate residual at medium watering volume for Selangor soil series.
Table 2. Physico-chemical properties of soil series.

| Parameter   | Selangor soil series | Serdang soil series |
|-------------|-----------------------|---------------------|
| Organic matter (%) | 26.7 | 0.65 |
| Sand (%)     | 2.7  | 52.4 |
| Clay (%)     | 45.4 | 30.5 |
| Silt (%)     | 51.9 | 17.1 |
| pH           | 4.3  | 5.34 |
| CEC          | 24.7 | 5.24 |

At the third layer (the lowest layer), glyphosate residues were still detected at all columns explaining that glyphosate was still moved and the presence of the soil organic matter content kept the concentration of glyphosate in the soil. Based on Figure 4 and Figure 5, the lowest glyphosate residue values were recorded at 15.66 mg/L at first layer and 14.20 mg/L at third layer for the 5.5 mL/L glyphosate concentration. Higher clay content in Selangor soil series as well as its fine grain size cause less soil pores and low air space. This is supported by Okada et al. [10] who stated that the small size of soil grains makes the movement of glyphosate is limited and minimized the water to be absorbed. This explained the high concentration of glyphosate residue concentration in first layer compared to third layer when different volumes of water are applied to Selangor soil series.

![Figure 4](image-url). Mean concentration of glyphosate residual at maximum watering volume for Serdang soil series.

In contrast to the Serdang soil series, the soils were sand texture and have a larger grain size than the clay grain size. The larger grain size causes broader soil pores and faster movement of water and herbicides in the Serdang soil series compared to the Selangor soil series. In addition, a low pH value of Selangor soil series makes the adsorption of glyphosate increased especially in first layer. Soils with a pH of less than 5 will have high adsorption on soil particles. For pH above 5, glyphosate will be ionized, the negative charge is increased and the ability for glyphosate to bind to soil particles is limited [11].
Figure 5. Mean concentration of glyphosate residual at maximum watering volume for Selangor soil series.

3.2 Glyphosate residue in water leachate
For water samples, the highest residual glyphosate concentration values detected at concentration doses of 5.5 mL/L and 11 mL/L were on Serdang soil series (Table 3). This indicates that the movement of glyphosate in water on sand-textured soils is higher compared to clay-textured soils. This is supported by Borggaard et al. [12] who stated that the concentration of glyphosate residue in water on sandy soils has low absorption capacity and slow decomposition rate compared to clay. The mobility potential of glyphosate through the soil column is influenced by the different volumes of water applied to the soil. Glyphosate leaching occurring in drains or drainage indicates a risk of contamination in groundwater but only on soils with shallow groundwater depths [12].

Table 3. Mean concentration of glyphosate residues in water at two watering volume.

| Soil series   | Serdang soil series | Selangor soil series |
|---------------|---------------------|----------------------|
| Water volume  | 250 ml              |                      |
| Mulch         | Recommended dose    | Double recommended  |
| Blank         | 3.21                | 3.41                 |
| EFB           | 2.94                | 2.98                 |
| OPT           | 2.97                | 3.04                 |
| K             | 3.17                | 3.38                 |
| Water volume  | 500 ml              |                      |
| Blank         | 2.9                 | 3.14                 |
| EFB           | 2.54                | 2.64                 |
| OPT           | 2.57                | 2.77                 |
| K             | 2.62                | 3.01                 |
4. Conclusions

This study showed that the use of mulch is possible to slow the glyphosate mobility. The results showed that glyphosate adsorbed slowly in Selangor soil series conversely in Serdang soil series based on the volume of water and mulch used. The suitable mulches used to adsorb glyphosate were EFB and OPT because the lowest glyphosate residue concentrations were recorded by both mulches at both glyphosate concentration doses compared to commercial mulches and columns without mulches.

References

[1] Khusairi A, Loh SK, Azman I, Hishamuddin E, Ong-Abdullah M, Mohd Noor Izzuddin Z, Razmah G. Sundram S & Ahmad Parveez G 2018 Oil Palm Economic Performance in Malaysia and R & D Progress in 2017 Journal of Oil Palm Research 30(2) 163-195
[2] Rosli NS, Harun S, Jahim JM & Othaman, R 2017 Chemical and Physical Characterization of Oil Palm Empty Fruit Bunch. Malaysian Journal of Analytical Sciences 21(1) 188-196
[3] Sanagi, MM 2018 Recent Advances in the Preparation of Oil Palm Waste-Based Adsorbents for Removal of Environmental Pollutants-a Review. Malaysian Journal of Analytical Sciences 22(2) 175-184
[4] Telkar SG, Singh AK, Kant K, Solanki SPS, Kumar D (2017) Types of Mulching and Their Uses for Dry-land Condition. Biomolecule Reports 9 1-4
[5] Mohamad R, Mohayidin MG, Wibaya W, Juraimi AS & Lassim MM 2010 Management of Mixed Weeds in Young Oil-Palm Plantation with Selected Broad-Spectrum Herbicides Pertanika Journal of Tropical Agricultural Science 33(2) 193-203
[6] Duke SO, Lydon J, Koskinen WC, Moorman TB, Chaney RL and Hammerschmidt R 2012 Glyphosate Effects on Plant Mineral Nutrition, Crop Rhizosphere Microbiota, and Plant Disease in Glyphosate-Resistant Crops. Journal of agricultural and food chemistry 60(42) 10375-10397
[7] Asla S, Iqbal A, Bourdat-Deschamps M, Recous S, Garnier P and Benoi P 2015 Effect of Rainfall Regimes and Mulch Decomposition on the Dissipation and Leaching Of S-Metolachlor and Glyphosate: A Soil Column Experiment. Pest Management Science 71(2)
[8] Siddiquee S, Shafawati SN & Naher L 2017 Effective Composting of Empty Fruit Bunches Using Potential Trichoderma Strains Biotechnology Reports 13(1-7)
[9] Mardiana-Jansar K and Ismail BS 2014 Residue Determination and Levels of Glyphosate in Surface Waters, Sediments and Soils Associated with Oil Palm Plantation in Tasik Chini, Pahang, Malaysia AIP Conf. Proc. 1614 795–802
[10] Okada E, Costa JL and Bedmar F 2016 Adsorption and Mobility of Glyphosate in Different Soils under No-Till and Conventional Tillage Geoderma 263(78-85)
[11] Tu M, Hurd C and Randall JM 2001 Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas
[12] Borggaard K and Gimsing AL. 2008. Fate of Glyphosate in Soil and the Possibility of Leaching to Ground and Surface Waters: A Review. Pest Management Science 64(4): 441-456

Acknowledgement

Mardiana-Jansar, K. was supported by the Universiti Kebangsaan Malaysia grant (Publication Reward Grant GP-2019-K016136) for conference fees and Ministry of Science, Technology and Innovation Malaysia grant (06-01-02-SF1367) for research activities. The authors would like to thanks the officer from Malaysian Palm Oil Board for sharing the research materials (oil palm waste).