PHYTOREMEDIATION OF CYPERMETHRIN: ENZYME ACTIVITY AND RESIDUE REDUCTION

Swe Sint[1], Aung Pyae Sone[2]

Abstract

Phytoremediation is an emerging technology that uses various plants to degrade contaminants including metals, and pesticides from soil and water. The aim of this research is to determine the insecticide residue and enzyme activity during phytoremediation with Sinngo and Hngetdaw-ni myet. In this study, the physicochemical properties of the soil samples were determined by conventional techniques, and EDXRF and AAS were used to determine metals before and after remediation (January 2023 to March 2023) in cold season. Phytoremediation was used to remediate cypermethrin-contaminated soil in the concentration range of 1-100 μg kg^{-1}. In addition, the potential phytoremediation efficiency of two plant species, Sinngo (*Eleusine indica (L.) Gaertn.)* and Hngetdaw-ni myet (*Axonopus compressus* (Swartz.) P. Beauv.) was evaluated. The residual insecticide and its metabolite, 3-phenoxybenzoic acid (3-PBA), extracted from the soil samples of the experimental plot were examined using a UV-Vis spectrophotometer. The highest phytoremediation efficiency was demonstrated by Sinngo and Hngetdaw-ni myet (89.6 and 87.4 % of PBA removal) in a 10-week period. The activities of urease and dehydrogenase enzymes were determined by the phenol-hypochlorite colourimetric and the Triphenyl Tetrazolium Chloride (TTC) assay methods. The urease enzyme activities (mg NH_4^+-N g^{-1} soil h^{-1}) in soils treated with Sinngo myet (5.46 ± 0.0206) and Hngetdaw-ni myet (4.45 ± 0.0113) were found to be higher the uncultivated soil (S_0) (1.34 ± 0.01419), and the dehydrogenase enzyme activities (µg TPF g^{-1} soil h^{-1}) in soils treated with Sinngo myet (0.0033 ± 0.0042) and Hngetdaw-ni myet (0.0026 ± 0.0000) were also increased the uncultivated soil S_0 (0.00011 ± 0.00046) in the field experiment. The results clearly demonstrated that Sinngo and Hngetdaw-ni myet showed great promising potential as phytoremediating agents for the further clean-up of insecticide contaminated soil.

Keywords: phytoremediation, enzyme activities, insecticide residue, EDXRF, AAS, Sinngo and Hngetdaw-ni-myet

Introduction

Pesticides enter the soil via direct application to control soil pests, spray drift during foliage treatment, release from granules, or from treated seeds in soil. Soil contamination can be caused by several factors, like improper management of urban and industrial waste; chemical spillage, commonly due to industrial activity; and excessive usage of fertilizers and pesticides in agriculture (Lombi and Hamon, 2005). Cypermethrin is one of the most widely used pyrethroid insecticides against different pests, and its use causes soil contamination. Cypermethrin is relatively stable to sunlight, although it is probable that photodegradation plays a significant role in the degradation of the product and its effects in soils are limited. Degradation in the soil occurs primarily through the cleavage of the ester linkage to give PBA and carbon dioxide. The half-life of cypermethrin in a typical fertile soil is between 8 and 16 days (Xie *et al*., 2002).

Phytoremediation is one of the most environmentally and cost-effective methods for the decontamination and detoxification of pesticide contaminated environments. Phytoremediation not only uses plants by several methods to contain or clean up toxic hazards but also has the benefit of being a relatively low-cost, natural solution to an environmental problem. Plants, soil, microbes, and contaminants are required in order to be successful in the application of phytoremediation (Aioub *et al*., 2019). Soil degradation occurs due to the changes in the physical, chemical, and biological properties of soil. Soil enzymes are a group of enzymes that

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inhabit soil and play a key role in maintaining the physical and chemical properties, fertility, and health of soil. Soil enzymes are the key players in biochemical processes of organic matter recycling in the soil system, and their activities are closely related to soil organic matter, soil physical properties, and microbial activity. The main role of urease enzyme activity is to allow the microorganisms to use urea as a source of nitrogen (Jingjing *et al.,* 2019). Dehydrogenase enzyme activity is considered as an indicator of the oxidative activity of soil microorganisms and increases significantly upon balanced fertilization (Jat *et al*., 2021). Colourimetric and spectrophotometric (UV-Vis) methods together or separately can be used in this sense, as well as conventional methods. Chemical compounds must be analyzed in complex samples, spectrophotometric measurements are useful for small pollutant concentrations (Pico and Kozmutza, 2007).

Materials and Methods

Collection and Preparation of Soil Samples

Soil samples were collected from the surface layer (0-20 cm depth) of the study site located in Shwepyithar Township, Yangon Region (16° 59' N latitude and 96° 4' E longitude). This site is usually cropped with chilli, tomato, and lady's fingers rotations using pyrethroid insecticides (including cypermethrin). However, there has been no treatment in these area for several years. For this field experiment, the soil samples were collected from January 2023 to March 2023 in cold season. In this experiment, soil samples were immediately sent to the laboratory and stored at room temperature for analysis. They were then stored in sampling plastic bags and labelled with sample codes, sampling dates, and sample location before measurements.

Figure 1. Sample collection site (Shwepyithar Township, Yangon Region)

Determination of Physicochemical Properties of Soil Sample

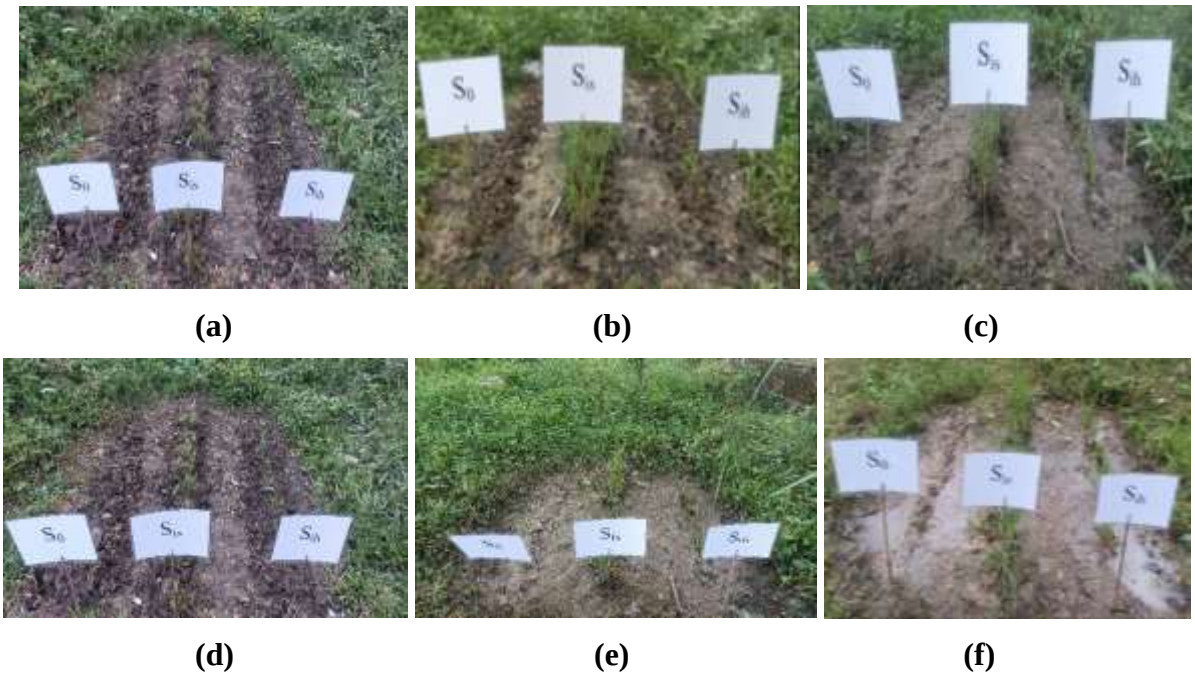
The moisture content of the soil sample was determined by the oven drying method, pH value by pH meter, electrical conductivity (EC) value by electrical conductivity meter, organic matter content by Walkley and Black method based upon the oxidizable organic matter content, total nitrogen (N) content by Kjeldahl's method, cation exchange capacity by the method of Kappen (Jaremko and Kalembasa, 2014), total phosphorus (P_2O_5) content by the spectrophotometric method of Olsen for neutral and alkaline soil, and potassium content by the ammonium acetate extraction method using a flame photometer.

Elemental Analysis of Soil Samples by EDXRF and AAS

Elemental analysis of the soil samples by energy dispersive X-ray fluorescence (EDXRF) and some elements (Fe, K, and Ca) contents by atomic absorption spectroscopy (AAS) techniques.

Study Design for Field Experiment

The soil samples collected from the farm in Shwepyithar Township, Yangon Region, from January 2023 to March 2023 (cold season) were analyzed to know the degradation of 3-PBA in the insecticide contaminated soil. Soil samples were prepared well by one deep ploughing and made into three parallel rows of 5 ft long planting beds spaced 12 inches from each other, treated with composted organic fertilizer (mixed with rice hull), and all the beds were sprayed with insecticide (cypermethrin). A 1 mL of each 0.0001 % cypermethrin solution was thoroughly mixed into each plot to get 100 μg cypermethrin per kg of soil. Plant maintenance was done from the beginning of planting until harvest. The temperature was kept at 32 °C during the day and 27 °C at night. Water was added to the soil in each bed every day to maintain the appropriate moisture content (Swe Sint, 2022).



(a) **(b)** **(c)**

(d) **(e)** **(f)**

Figure 2. Planting of Sinngo and Hngetdaw-ni myet (a) 0-week (b) 2-weeks (c) 4-weeks (d) 6-weeks (e) 8-weeks and (f) 10-weeks in cold season

The field study was performed with natural light. The study was continued after the screening period using two plant species that grew well in the cypermethrin contaminated soil. Samples of the soil were then taken for analysis at 0, 2, 4, 6, 8, and 10 weeks (with three replicates for each time) to determine the amount of 3-PBA formed and enzyme activities over the course of three months. The soil samples were then placed in sampling plastic bags and labeled with sample codes, sampling dates, and sample locations. The field experiments were arranged according to a Randomized Complete Block (RCB) design that consisted of three treatments: (1) only cypermethrin contaminated soil (S_0), (2) S_0 with insecticide and Sinngo myet plant (S_{is}) and (3) S_0 with insecticide and Hngetdaw-ni plant (S_{ih}). A total of fifty-four plots were established (Figure 2).

Extraction and Characterization of Insecticide Residue

3-PBA was extracted from 10 g of soil samples using a methanol and dichloromethane (3:1, v/v) mixture and placed in a shaker at 150 rpm for 30 min. The supernatant liquid was centrifuged at 5000 rpm for 15 min three times. The residual insecticide (as its metabolite 3-PBA) in extracted soil samples from the experimental plot was examined by using a UV-Vis spectrometer at 247 nm (Xie *et al*., 2008) as shown in Figure 3.

Figure 3. Extraction of insecticide residue in various treatments in cold season

Determination of Enzyme Activities

Soil enzymes play an important role in organic matter decomposition and nutrient cycling. Their activities are attractive as indicators for monitoring various impacts on soil because of their central role in the soil environment. The activity of the urease enzyme (mg NH_4^+-N g^{-1} soil h^{-1}) was measured by phenol-hypochlorite colourimetric methods (Jingjing *et al*., 2015). A 10 g of fresh soil was placed in a 100 mL volumetric flask and treated with 1 mL of toluene, 10 mL buffer (pH-7) and 5 mL of freshly prepared 10 % urea solution. After a thorough mixing, the flask was incubated for 3 h at 37 ºC in the dark. After incubation, the volume was made up to 100 mL with distilled water and then filtered. 0.5 mL of the filtrate was taken into a 25 mL volumetric flask, and 5 mL of distilled water was added. Then 2 mL of phenolate solution and 1.5 mL of sodium hypochlorite solution were added. The final volume of the flask was increased up to 25 mL with distilled water, and the blue colour was read out with the spectrophotometer at 630 nm (Figure 4).

(a) **(b)**

Figure 4. (a) Incubating at 37 ºC for 3 h (b) greenish blue colour of urease enzyme in cold season

(a) **(b)**

Figure 5. (a) Incubating at 30 ºC for 24 h (b) pink colour of dehydrogenase enzyme in cold season

Dehydrogenase enzyme activity was determined by the 2,3,5-Triphenyl Tetrazolium Chloride (TTC) reduction technique (Cycon *et al*., 2010). Five grams of soil were placed in a beaker and carefully mixed with 0.1 g of $CaCO_3$ and 1.5 mL of distilled water added to the mixture. Then, 1 mL of 1 % TTC solution was added, and the beakers were incubated at 30 ºC for 24 h after plugging with cotton. The resulting slurry was filtered and Triphenyl Formazan (TPF) was extracted with successive aliquots of methanol in a 50 mL volumetric flask. The absorption of the pink colour was read out with a spectrometer at 485 nm (Figure 5).

Statistical Analysis

Values were expressed as means ± standard deviation (SD). All data were tested for normality and homogeneity using Leven's test. All results were conducted with three replicates. The experimental data were statistically analyzed by one-way analysis of variance (ANOVA) using Excel.

Results and Discussion

Physicochemical Properties of Soil Sample

In this study, the soil has a sandy loam texture with very low nitrogen, low organic carbon, electrical conductivity, and phosphorus, high CEC, and medium K_2O contents. The moisture content of the contaminated soil was found to be 1.87 % and the pH value was 7.37. Soil moisture is the water stored in the soil and is affected by precipitation, temperature, soil characteristics, and more. Air and water, the gas and liquid phases, exist in the pores. The size of the soil particles and pores affect how much water a soil can hold, and how that water moves through the soil. From these observations, the pH range of the contaminated farm soil was found to be moderately alkaline. pH is important because it can alter the availability of nutrients to the plants and also affect the activity of the roots and microbes.

The electrical conductivity value of the contaminated soil was found to be 0.38 mS/cm. The organic carbon content of the contaminated soil was found to be 0.24 %. The humus content of the contaminated soil was found to be 0.42 % and phosphorus was 4.89 ppm. The total nitrogen value of the contaminated soil was found to be 0.107 %. Thus, the decrease in nitrogen levels reduces the leaf area, chlorophyll content, photosynthesis, and biomass production. The CEC values of calcium Ca^{2+} (5.43 meq/100 g), Mg^{2+} (18.33 meq/100 g), K^+ (0.27 meq/100 g), and Na^+ (1.64 meq/100 g) were observed (Table 1). Cation exchangeable capacity (CEC) is important for maintaining adequate quantities of plant available calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+).

Table 1. Physicochemical Properties of Soil Sample in Cold Season

Test Parameter	Content
Texture	Sandy loam
Sand (%)	57.98
Silt (%)	24.90
Clay (%)	17.12
Moisture (%)	1.87
pH	7.37
Electrical Conductivity (mS/cm)	0.38
Organic carbon (%)	0.24
Humus (%)	0.42
Total Nitrogen (%)	0.107
CEC (meq/100 g)	25.67
Phosphorus, P_2O_5 (ppm)	4.89
K_2O (mg/100 g)	12.84
Exchangeable Ca^{2+} (meq/100 g)	5.43
Exchangeable Mg^{2+} (meq/100 g)	18.33
Exchangeable K^{+} (meq/100 g)	0.27
Exchangeable Na^{+}(meq/100 g)	1.64

Relative Abundance of Elements in Soil Samples by EDXRF and AAS Analysis

The relative abundance of some elements: silicon, iron, aluminium, potassium, titanium, calcium, sulphur, manganese, chromium, zinc, copper, and rubidium in insecticide-contaminated soil was determined by EDXRF before and after remediation in cold season. The elements such as iron, potassium, and calcium were determined by AAS before and after remediation (Figure 6 and Table 2).

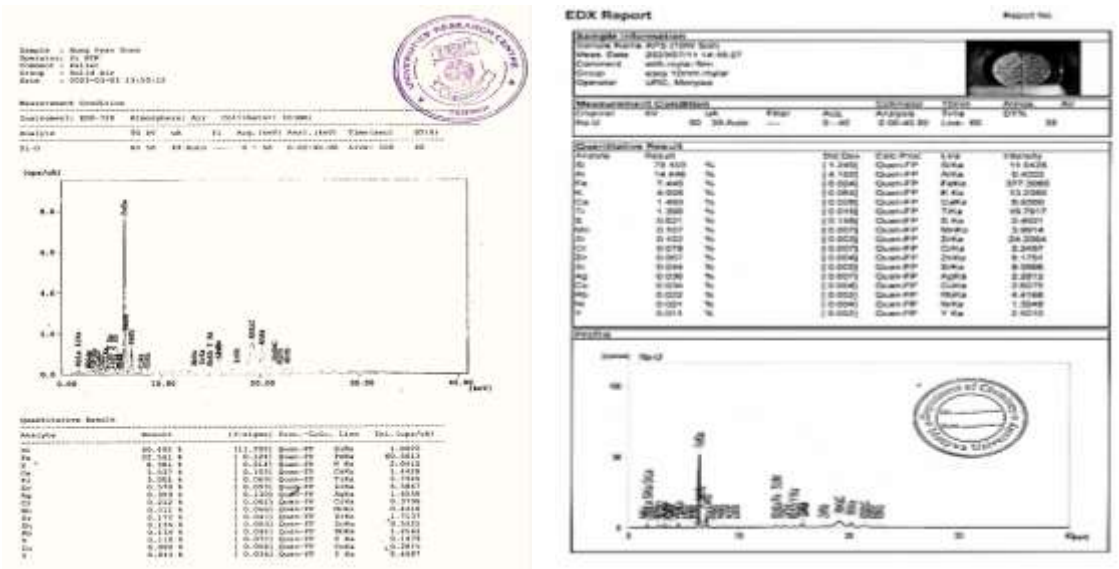
According to the EDXRF spectrum, the insecticide-contaminated soil contained silicon (Si) was the major constituent and iron (Fe) was the second major constituent and other elements were trace constituents: potassium (K), calcium (Ca), titanium (Ti), manganese (Mn), zirconium (Zr), barium (Ba), chromium (Cr), strontium (Sr), zinc (Zn), yttrium (Y), copper (Cu), and rubidium (Rb). All are composed of the insecticide-contaminated soil, which contained high amounts of Si, Fe, K, Ca, and Ti (Table 2). The high content of silicon helps resist the damage to crops caused by pathogenic microorganisms and that of other elements functions as plant nutrients.

Iron is a required plant nutrient for normal plant growth and reproduction. Iron is required in small amounts and is called a "micronutrient." Iron is a challenging plant nutrient to work with because of its reactions in the soil and its plant physiology. Sulphur is one of the essential nutrients that is required for the adequate growth and development of plants. Sulphur is a structural component of protein disulphide bonds, amino acids, vitamins, and cofactors. Most of the sulphur in soil is present in organic matter. Manganese is an important micronutrient for plant

growth and development and sustains metabolic roles within different plant cell compartments. The metal is an essential cofactor for the oxygen-evolving complex of the photosynthetic machinery, catalyzing the water-splitting reaction in the photosystem. The other nutrient elements, chromium, strontium, zinc, copper, and rubidium, are used by higher plants in very small amounts, thereby justifying the name "micronutrients" or "trace elements." Titanium, applied via roots or leaves in growth experiments, stimulates plant growth in a species-specific manner. It can stimulate chlorophyll content, enzyme activity, and the uptake of major and minor nutrients.

Table 2. Elemental Analysis of the Soil Sample by EDXRF in Cold Season

Elements	Relative Abundance (%)	
	Before Remediation	After Remediation
Silicon	60.492	70.103
Aluminum	-	14.446
Iron	22.561	7.445
Potassium	8.381	4.008
Titanium	3.001	1.396
Calcium	3.537	1.460
Sulphur	-	0.621
Manganese	0.211	0.107
Chromium	0.212	0.078
Zinc	0.135	0.067
Strontium	0.172	0.044
Copper	0.082	0.034
Rubidium	0.134	0.022



(a) **(b)**

Figure 6. EDXRF spectra of contaminated soil from Shwepyithar Township (a) before remediation (b) after remediation in cold season

According to AAS, iron (Fe) was found to be 29.11 ppm, potassium was 2.840 ppm and calcium was 0.786 before remediation. After remediation, iron (Fe) was found to be 34.05 ppm, potassium was 4.249 ppm and calcium was 9.345 ppm, respectively (Table 3). According to this

data, the AAS values such as iron, potassium, and calcium in soil after remediation are greater than those of before remediation. Potassium is essential in nearly all processes needed to sustain plant growth and reproduction. Plants deficient in potassium are less resistant to drought, excess water, and high and low temperatures.

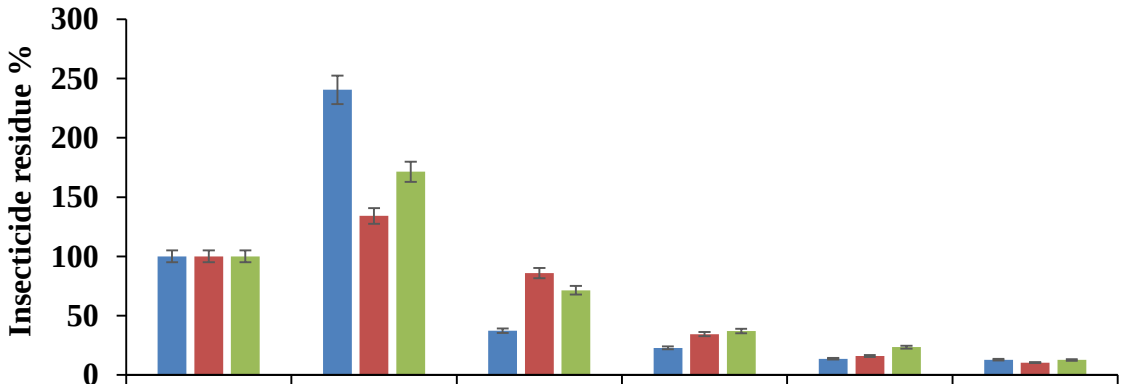
Table 3. Elemental Analysis of the Soil Sample by AAS in Cold Season

Elements	Contents (ppm)	
	Before Remediation	After Remediation
Iron	29.110 ± 0.101	34.050 ± 0.0680
Potassium	2.840 ± 0.0377	4.249 ± 0.1353
Calcium	0.786 ± 0.0451	9.345 ± 0.0945

Potassium triggers the activation of enzymes and is essential for the production of adenosine triphosphate (ATP). Calcium plays a vital role in plant growth, specifically cell wall formation, cell division, and pollination. Calcium also promotes healthy soil structure by loosening soils and stabilising organic matter, which increases soil water-holding and nutrient-holding capacity. Most soils have enough or too much calcium for plants to use as a nutrient.

Insecticide Residue Percent in Contaminated Soil Samples

The most important photodegradation product, 3-phenoxybenzoic acid (3-PBA), and, to some extent, the amide of the intact ester do not differ greatly from those resulting from biological degradation. Degradation in the soil occurs primarily through cleavage of the ester linkage to give PBA, and carbon dioxide. Some carbon dioxide is formed through the cleavage of both the cyclopropyl and phenyl rings under oxidative conditions. Cypermethrin is adsorbed very strongly on soil particles, especially in soils containing large amounts of clay or organic matter.



	0-weeks	2-weeks	4-weeks	6-weeks	8-weeks	10-weeks
S0	100	240.6	37.3	22.8	13.6	12.8
Sis	100	134.1	85.9	34.4	15.9	10.4
Sih	100	171.4	71.4	37.1	23.4	12.6

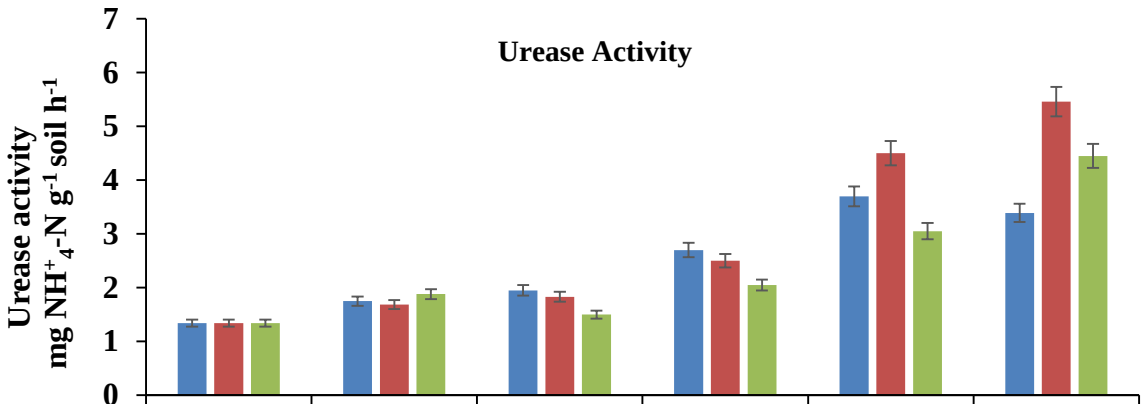
Figure 7. Insecticide residue (PBA) percent in contaminated soil treated with Sinngo and Hngetdaw-ni myet in cold season

Many remediation technologies hold enormous potential for the clean-up of hazardous pollutants. Sinngo myet has the greatest efficiency of removal, and the efficiency decreased in the following order: Sinngo myet > Hngetdaw-ni myet in cold season. These grasses reduced the cypermethrin in the soil, preventing the normal uptake of the cypermethrin by the plants in the

phytoremediation experiments. These grasses were combined with phytoremediation and have been investigated for the removal of insecticides from contaminated soil by using UV-Vis spectrophotometers. The percentages of insecticide residue (3-PBA) in the S_0, S_{is} and S_{ih} treatments were found to be 240.6 %, 134.1 % and 171.4 %. PBA formed through 2 weeks of experiments and 12.8 %, 10.4 % and 12.6 % PBA removal of cultivated soil formed through 10 weeks of experiments when compared to S_0 uncultivated soil (100 %) in the 0-week treatment (Figure 7). All treatments were found to have the phytoremediation efficiency for insecticide contaminated soil. Among them, Sinngo myet had the better degradation efficiency.

Enzyme Activities Variation in Different Treatments

The degradation of cypermethrin in soil is mostly attributed to microorganisms. Urease and dehydrogenase activities are appropriate substitute biomarkers for general microbial activities in soils. Urease and dehydrogenase activities significantly increased over the course of the period (January 2023 to March, 2023) in cold season.



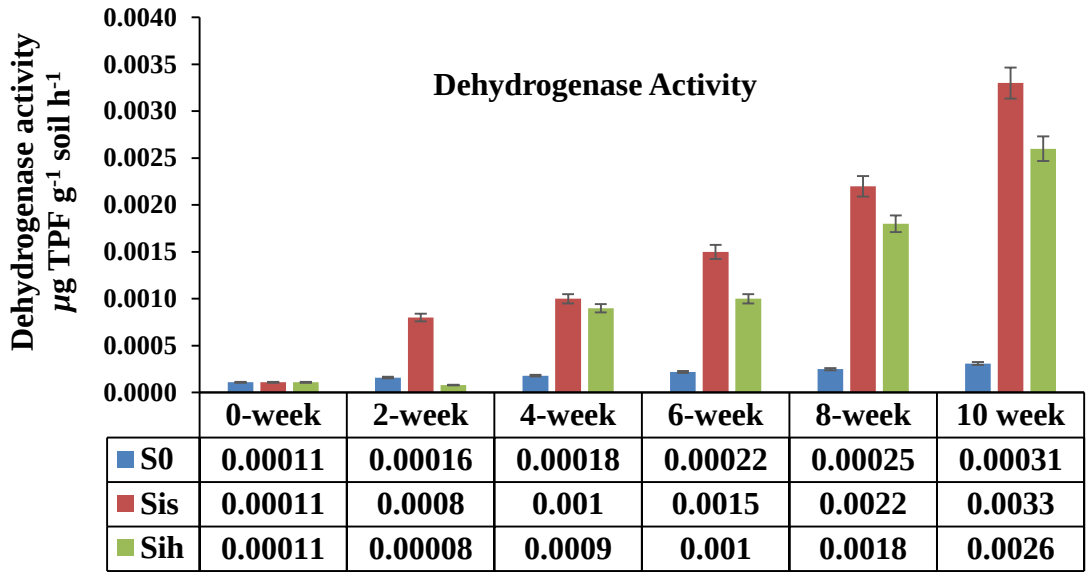
	0-week	2-week	4-week	6-week	8-week	10 week
S0	1.34	1.75	1.95	2.7	3.7	3.39
Sis	1.34	1.686	1.83	2.5	4.5	5.46
Sih	1.34	1.88	1.5	2.05	3.05	4.45

Figure 8. Soil urease enzyme activity in insecticide contaminated soil treated with Sinngo and Hngetdaw-ni myet in cold season

After 2 weeks, the urease activities were found in uncultivated soil (control) 1.75 (S_0-soil without plant), 1.686 (S_{is}- soil with Sinngo myet), and 1.88 (S_{ih}- soil with Hngetdaw-ni myet) mg NH_4^+-N g^{-1} soil h^{-1}. After 4 weeks, the urease activities were found in uncultivated soil 1.95 (S_0), 1.83 (S_{is}), and 1.5 (S_{ih}) mg NH_4^+-N g^{-1} soil h^{-1}. After 6 weeks, the urease activities were found in uncultivated soil 2.7 (S_0), 2.5 (S_{is}) and 2.05 (S_{ih}) mg NH_4^+-N g^{-1} soil h^{-1}. After 8 weeks, the urease activities were found in uncultivated soil 3.7 (S_0), 4.5 (S_{is}), and 3.05 (S_{ih}) mg NH_4^+-N g^{-1} soil h^{-1}. After 10 weeks, the urease activities were found in uncultivated soil 1.34 (S_0), 5.46 (S_{is}), and 4.45 (S_{ih}) mg NH_4^+-N g^{-1} soil h^{-1} (Figure 8). The percentage of urease enzyme activity in Sinngo and Hngetdaw-ni myet were found to be increased 96.34 and 93.08 % in 2-weeks, 93.84 and 76.92 % in 4-weeks, 92.59 and 75.92 % in 6-weeks, and 121.62 and 82.43 % in 8-weeks, and 161.06 and 131.26 % in compared with S_0 (assumed as 100 %) through 10 weeks experiment (Figure 8).

After 2 weeks, the dehydrogenase enzyme activities were found in uncultivated soil 0.00011 (S_0-soil without plant), 0.0008 (S_{is}-soil with Sinngo myet), and 0.00008 (S_{ih}-soil with

Hngetdaw-ni myet) μg TPF g^{-1} soil h^{-1}. After 4 weeks, the dehydrogenase activities were found in uncultivated soil 0.00018 (S_0), 0.001 (S_{is}) and 0.0009 (S_{ih}) μg TPF g^{-1} soil h^{-1}. After 6 weeks, the dehydrogenase activities were found in uncultivated soil 0.00022 (S_0), 0.0015 (S_{is}) and 0.001 (S_{ih}) μg TPF g^{-1} soil h^{-1}. After 8 weeks, the dehydrogenase activities were found in uncultivated soil 0.00025 (S_0), 0.0022 (S_{is}) and 0.0018 (S_{ih}) μg TPF g^{-1} soil h^{-1}. The dehydrogenase activities were found in uncultivated soil 0.00031 (S_0), 0.0033 (S_{is}) and 0.0026 (S_{ih}) μg TPF g^{-1} soil h^{-1} in 10 weeks (Figure 9).



	0-week	2-week	4-week	6-week	8-week	10 week
S0	0.00011	0.00016	0.00018	0.00022	0.00025	0.00031
Sis	0.00011	0.0008	0.001	0.0015	0.0022	0.0033
Sih	0.00011	0.00008	0.0009	0.001	0.0018	0.0026

Figure 9. Soil dehydrogenase enzyme activity in insecticide contaminated soil treated with Sinngo and Hngetdaw-ni myet myet in cold season

The percentages of dehydrogenase enzyme activity in Sinngo and Hngetdaw-ni myet were found to be increased 80 and 80 % in 2-weeks, 82 and 80 % in 4-weeks, 85.33 and 78 % in 6-weeks, 88.636 and 70.454 % in 8-weeks, and 90.60 and 88 % in compared with S_0 (assumed as 100 %) through the 10 weeks experiment. The present study showed that urease and dehydrogenase enzyme quantities were improved by phytoremediation with Sinngo and Hngetdaw-ni myet. The degradation of cypermethrin in soil is mostly attributed to microorganisms. Urease and dehydrogenase activities are appropriate substitute biomarkers for general microbial activities in soils. Urease and dehydrogenase activities significantly increased over the course of 10-weeks.

Conclusion

This research focused on the determination of insecticide residue and enzyme activity during phytoremediation with Sinngo and Hngetdaw-ni myet over a three-month period (January 2023 to March 2023). The physicochemical properties of the soil sample have a sandy loam texture. The pH value was moderately alkaline. The contents of cation exchange capacity (CEC) and electrical conductivity (EC) were relatively low. Exchangeable calcium and magnesium were moderately high, while available potassium was very low. The soil organic carbon content was low indicating a relatively low level of organic matter. The total nitrogen content was also low, suggesting low nutrients were in the soil. According to EDXRF, the insecticide-contaminated soil contained silicon (Si) as the major constituent, iron as the second major constituent, and other elements are trace constituents. The percentages of silicon before remediation are less than those of after remediation. The values of iron, potassium, titanium, calcium, manganese, chromium, zinc, strontium, copper and rubidium before remediation are greater than those of after

remediation. Aluminium and sulphur are present after remediation but absent before remediation. The AAS values, such as iron, potassium, and calcium, after remediation are greater than before remediation. In the field experiment, the highest phytoremediation efficiency was also demonstrated by Sinngo and Hngetdaw-ni myet (89.6 and 87.4 % of PBA removal) in 10 weeks. The results of the study have shown that, when phytoremediation using Sinngo and Hngetdaw-ni myet is applied, the levels of cypermethrin as its primary metabolite (3-PBA) can be lowered. In cold season, **t**he urease enzyme activity of cultivated soil in Sinngo myet (5.46 ± 0.0206 mg NH_4^+-N g^{-1} soil h^{-1}) and Hngetdaw-ni myet (4.45 ± 0.0113 mg NH_4^+-N g^{-1} soil h^{-1} was significantly higher than that of uncultivated soil (S_0) (1.34 ± 0.01419). The dehydrogenase enzyme activity of cultivated soil in Sinngo myet (0.0033 ± 0.0042 μg TPF g^{-1} soil h^{-1}) and Hngetdaw-ni myet (0.0026 ± 0.0000 μg TPF g^{-1} soil h^{-1}) in 10 weeks were higher than uncultivated soil, S_0 (0.00011 ± 0.00046) in a 0 week period. In the comparison of Sinngo and Hngetdaw-ni myet, the urease and dehydrogenase activities of Sinngo myet were better than those of Hngetdaw-ni myet. The result clearly demonstrated that phytoremediation not only reduces the insecticide residue but also increases the urease and dehydrogenase enzyme activities in the soil.

Acknowledgements

The authors would like to express their profound gratitude to Professor and Head, Dr Kyi Kyi Khine, Department of Chemistry, Sittway University, for her kind encouragement.

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