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Weed Control Efficacy and Soil Activity of a New Promising Bioherbicide 'WeedLock'

(Keberkesanan Kawalan Rumpai dan Aktiviti Tanah 'WeedLock' Bioherbisida Baharu yang Berpotensi)

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ABSTRACT

The development of plant-based bioherbicides has gained the interest of researchers and acceptability from the farmers to control weeds in order to reduce their overdependence on chemical herbicides. Therefore, this research investigated the efficacy and soil activity of WeedLock, a new plant-based bioherbicide. In the efficacy study, WeedLock was applied at 672.75, 1345.50 (recommended dose), 2691.00 L ha^{-1} over the untreated (control) on weeds in mixed-culture (*Ageratum conyzoides* L., *Eleusine indica* (L.) Gaertn., and *Cyperus iria* L). For soil activity, *Zea mays* L. seedlings were grown in different soil textures, namely clay, sand, sandy clay loam, and peat soil and WeedLock was applied to each soil type at 1345.50 L ha^{-1} with a pipette as a soil drench method. After 21 days, the plants were harvested, including roots and the soil in trays that were previously sprayed with WeedLock, and the trays were further maintained for 1, 2, 4, 8, 12 and 16 weeks, respectively, before new seedlings were grown on the same soil. WeedLock at 1345.50 L ha^{-1} showed severe injury on weeds and produced 98.15% weed control efficacy compared to untreated (control). For soil activity, WeedLock did not show any significant decrease in growth and development of *Z. mays,* and the injury scale was 1.00, which means all leaves of *Z. mays* remained green, and the plants were actively growing on the WeedLock treated soils. Thus, it can be concluded that WeedLock has excellent weed control efficacy with negligible soil activity.

Keywords: Efficacy; soil activity; soil textures; WeedLock

ABSTRAK

Pembangunan bioherbisida berasaskan tumbuhan telah menarik minat penyelidik dan penerimaan daripada petani untuk mengawal rumpai bagi mengurangkan kebergantungan berlebihan mereka terhadap racun herba kimia. Oleh itu, penyelidikan ini mengkaji keberkesanan dan aktiviti tanah WeedLock, bioherbisida baharu berasaskan tumbuhan. Dalam kajian keberkesanan, WeedLock telah digunakan pada 672.75, 1345.50 (dos yang disyorkan), 2691.00 L HA^{-1} ke atas yang tidak dirawat (kawalan) pada rumpai dalam kultur campuran (*Ageratum conyzoides* L., *Eleusine indica* (L.) Gaertn., dan *Cyperus iria* L). Untuk aktiviti tanah, anak benih *Zea mays* L. ditanam dalam tekstur tanah yang berbeza, iaitu tanah liat, pasir, tanah liat berpasir serta tanah gambut dan WeedLock digunakan untuk setiap jenis tanah pada 1345.50 L ha^{-1} dengan pipet sebagai kaedah basah tanah. Selepas 21 hari, tanaman dituai, termasuk akar dan tanah dalam dulang yang sebelum ini disembur dengan WeedLock dan dulang terus dikekalkan masing-masing selama 1, 2, 4, 8, 12 dan 16 minggu, sebelum anak benih baru ditanam pada tanah yang sama. WeedLock pada 1345.50 L ha^{-1} menunjukkan kecederaan teruk pada rumpai dan menghasilkan 98.15% keberkesanan kawalan rumpai berbanding yang tidak dirawat (kawalan). Untuk aktiviti tanah, WeedLock tidak menunjukkan sebarang penurunan ketara dalam pertumbuhan dan perkembangan *Z. mays* dan skala kecederaan ialah 1.00, yang bermaksud semua daun *Z. mays* kekal hijau dan tumbuhan sedang tumbuh secara aktif pada tanah yang dirawat WeedLock. Oleh itu, boleh disimpulkan bahawa WeedLock mempunyai keberkesanan kawalan rumpai yang sangat baik tanpa aktiviti tanah yang ketara.

Kata kunci: Aktiviti tanah; keberkesanan; tekstur tanah; WeedLock

Introduction

Environmental pollution is the most pressing concern relating to sustainable development. Over the past few years, agriculture has been confronted by increasing environmental pollution, primarily caused by various factors linked by a specific goal: maximizing crop yield (Mahmoud 2017). Agriculture sector is facing serious challenges in order to ensure high yield while also protecting the environment and human health. The most concerning element is the injudicious and/or overuse of chemical pesticides in the agro-ecosystem for weed and pest control (Hasan et al. 2021). Weed control using herbicides has been practiced for decades to prevent yield loss in agricultural crops. However, the environmental conditions have recently been addressed due to extensive herbicide use in agro-ecosystems.

Although herbicides effectively control weeds in the field, unfortunately, it can also leave undesired toxic residues in the soil that are hazardous to the environment (Janaki et al. 2015). The presence of herbicide residue in the environment has emerged as a significant concern for public health. Certain herbicides have long persistence throughout the environment and can spread far beyond the application site (Kumar et al. 2021). Herbicide residue can quickly move across soil surface and groundwater. Herbicide persistence in the environment is influenced by a variety of factors, including leaching, runoff, photodegradation, biodegradation by soil microorganisms, drift, and herbicide molecules binding to soil particles. Chemical herbicides are mainly preferred by farmers to control weeds due to their higher efficacy, affordable cost and more rapid out return. With the migration of labor from agriculture to industry; and off-target toxicity including weed biotypes resistant to existing synthetic herbicides, researchers are motivated to think about alternatives (Motmainna et al. 2021).

In this context, the development of bioherbicides has provided a new avenue for developing eco-friendly farming practices that both increase crop yields and maintain ecosystem stability (Scavo, Abbate & Mauromicale 2019). Bioherbicides comprise natural active substances used to control target organisms in crops (Kumar et al. 2021). Once released into the soil, they may be subjected to sorption, transport, and degradation (abiotic and biotic processes). The multiple modes of action of bioherbicide also reduce the chance of resistance emergence (Hubbard et al. 2016). Unfortunately, despite the widespread interest in natural alternatives, only a few bioherbicides are commercially available; WeedLock is considered a post-emergence bioherbicide to manage weeds (Hasan et al. 2021).

Soil also plays a crucial role, as it acts as a matrix for the adsorption and transportation of bioherbicides. Soil texture defines the size of soil particles and their distribution into textural classes. Soil texture has a significant impact on the leaching of allelochemicals, and, subsequently, the phytotoxic effects of these compounds are strongly influenced on plants (Sangeetha & Baskar 2015). The biotic and abiotic factors profoundly change the bioherbicide concentrations in the soil (Sangeetha & Baskar 2015). Moreover, the quantities of bioherbicidal compounds are also considerably affected by soil moisture, pH, organic matter, bulk density, and particle size (Saini, Singh & Deb 2020). Several herbicides are tightly bound to soil particles due to their low solubility and/or high hydrophobicity (Tayeb et al. 2016). The herbicidal compounds are more sorbed to clay soil because clay particles and organic matter bind the herbicide molecules tightly compared to other textural soil classes (Tayeb et al. 2019). Understanding the influence of these characteristics can impact the sorption and desorption of herbicides and lead to selecting herbicide doses appropriate for the soil-specific properties (Gomes et al. 2017).

To date, there are just a few studies that describe the weed control efficacy, soil activity and environmental fate of commercial bioherbicides. WeedLock is a plant-based ready-to-use bioherbicide developed from *Solanum habrochaites* S. Knapp & D.M. Spooner (wild tomato) plant extract and marketed locally in Malaysia by EntoGenex Industries Sdn. Bhd since 2017. Although numerous plant extracts have been found to have bioherbicidal potential but the weed control efficiency and soil activity of commercial plant-based bioherbicide are scant so far. Hence, our present study aimed to evaluate weed control efficacy and determine the soil activity of WeedLock in different soil textures.

MATERIALS AND METHODS

EXPERIMENTAL LOCATION, TREATMENTS AND DESIGN

The weed control efficacy experiment was conducted from November to December 2020 and soil activity of WeedLock in different soil textures experiment was performed from January to June 2021 in the Field 15 (Ladang 15), Faculty of Agriculture, Universiti Putra Malaysia, Selangor, Malaysia. For weed control efficacy, a total of 12 healthy seedlings of three different species, namely *A. conyzoides*, *E. indica,* and *C. iria* were transplanted and grown together in plastic pots (15 cm diameter), filled with top soil at ¾ full. Four uniform plants of each weed species were maintained in each pot. WeedLock was sprayed when *A. conyzoides* reached 4-6-leaf stage, and *E. indica* and *C. iria* reached 2-3-leaf stage. WeedLock was applied at 672.75 (half recommended rate), 1345.50 (recommended rate), 2691.00 L ha^{-1} (double recommended rate) and control (untreated) using a 1 L sprayer. A four-replicate randomized complete block design (RCBD) was set for the experiment. Visual assessments of weed injury were performed at 1, 7, 14, and 21 days following herbicide treatments. The injury scale (Sadi & Saeedipour 2015) was used to rate injury symptoms. Weeds were harvested at 1 cm above ground at 21 days after treatment (DAT) and the dry weight was taken after oven-drying the samples at 65 °C for 72 h. The weed control efficacy was calculated according to Hasan et al. (2021):

$$\text{Weed control efficiency (\%)} = \frac{\text{Dry weight of untreated pot} - \text{Dry weight of treated pot}}{\text{Dry weight of untreated pot}} \times 100$$

To evaluate the soil activity of WeedLock in different soil textures, *Z. mays* (known to be sensitive to herbicides) was grown in trays on different soil textures, namely clay, sand, sandy clay loam, and peat soil. The soils were collected from Tanjung Karang (3.4264° N latitude and 101.1767° E longitude), Kuala Selangor (clay); Lombong (2.9690° N latitude and 101.5566° E longitude), Batu cave (sand); Ladang Kongi (3.0077° N latitude and 101.7026° E longitude), Taman Pertanian Universiti, UPM (sandy clay loam) and TKPM Sg. Blankan (2.6966° N latitude and 101.6672° E longitude), Sepang (peat). The seeds of *Z. mays* were purchased from the Green World Genetics Sdn. Bhd., Malaysia. Ten equal-size healthy *Z. mays* seedlings were grown in each tray (40 cm × 30 cm × 10 cm). WeedLock bioherbicide was applied at 1345.50 L ha^{-1} (recommended rate) to each type of soil texture in the tray with a pipette as a soil drench method (Shrestha 2009) when *Z. mays* seedlings were 14 days old. Precautions were taken to prevent bioherbicide application directly onto the plant foliage or stem. Untreated soils with plants were used as a control. After 21 days, the plants were harvested (including roots) from different soils (clay, sand, sandy clay loam, and peat). The roots were separated and cleaned carefully to remove soil particles. Injury symptoms, plant height, leaf area, total chlorophyll, root length, fresh weight, and dry weight were taken. Plants with retaining green leaves with active growth were considered as no injury (injury scale 1.00). After harvest, clay, sand, sandy clay loam, and peat soils (which were previously treated with WeedLock, as mentioned above) were further maintained for different time intervals, namely 1, 2, 4, 8, 12, and 16 weeks. After each interval, the soil was mixed thoroughly, and then *Z. mays* was grown again in the same trays. Assessment on germination (%), plant height, injury symptoms, fresh, and dry weight was done at 21 days after seeds were sown. The experiment was arranged in randomized complete block design (RCBD) with four replicates.

SOIL ANALYSIS

In our study, four types of soils were used, namely clay, sand, sandy clay loam, and peat. All the experimental soils were collected up to 20 cm depth using a 5 cm diameter steel auger. The soil samples were then air-dried, pulverized, and passed by a sieve (2 mm). The pipette method was used to measure the particle size of the soil samples (Teh & Talib 2006). The experimental soil textures were classified following the classification system of USDA (Table 1). Soil pH was measured by a digital pH meter (soil and distilled water ratio 1:2.5) (Benton 2001). Exchangeable cations were determined by the leaching method using ammonium acetate (Schollenberger & Simon 1945) and analyzed by the atomic absorption spectrophotometer (AAS). CNS analyzer (LECO, Corporation, St. Joseph, USA) measured the total carbon, nitrogen and sulphur in the soil.

TABLE 1. Textural classification and physicochemical properties of experimental soils

	Clay	Sand	Sandy clay loam	Peat
Sand (%)	6.53	90.95	58.80	21.03
Silt (%)	29.70	2.57	11.77	42.20
Clay (%)	63.77	6.48	29.43	36.76
pH	5.11	4.86	4.94	5.13
Total C (%)	2.62	0.91	1.47	2.03
Total N (%)	0.19	0.04	0.08	0.14
Total S (%)	0.11	0.02	0.07	0.09
Exchangeable Ca ($cmol_c\ kg^{-1}$)	1.71	0.91	1.37	1.82
Exchangeable Mg ($cmol_c\ kg^{-1}$)	5.67	0.42	2.12	6.65
Exchangeable K ($cmol_c\ kg^{-1}$)	0.59	0.12	0.23	0.73

MORPHOLOGICAL CHARACTERISTICS

The plant height and root length were measured using a measuring tape and the height was measured from the plant base to the tip of the highest leaf. Leaf area meter (LI-3000, Li-COR) was used to measure the leaf area and chlorophyll meter (SPAD-502) was used to determine chlorophyll content and expressed as a SPAD value (Motmainna et al. 2021). The fresh weight of *Z. mays* was recorded immediately after harvest, and the dry weight was taken after oven-drying at 65 °C for 72 h.

STATISTICAL ANALYSIS

Data analysis was carried out with ANOVA using SAS (statistical analysis system) software, version 9.4 (Cary, NC, USA), and the Tukey studentized range test was used to compare the means with 5% probability.

RESULTS

INJURY SYMPTOMS

The herbicide efficacy was determined by observing the injury symptoms of weeds in mixed-culture at 1, 7, 14, and 21 DAT (Figure 1). The result showed that injury symptom was influenced significantly ($p \leq 0.05$) by the WeedLock application. The visual injury was higher in treated weeds than untreated (control). At 1 DAT, T_1 (672.75 L ha^{-1}) exhibited lower injury symptom while T_2 (1345.50 L ha^{-1}) and T_3 (2691.00 L ha^{-1}) showed higher injury symptoms in tested plants. At 7 DAT, T_2 (1345.50 L ha^{-1}) and T_3 (2691.00 L ha^{-1}) produced severe damage with an injury scale of 8.99 and 9.00, respectively, which were significantly different from other treatments. Similar results were observed at 7, 14 and 21 DAT. All weeds were completely killed (100% control) by T_3 (2691.00 L ha^{-1}) application rate of WeedLock at 7, 14 and 21 DAT with an injury scale of 9.00.

WEED CONTROL EFFICACY

Weed control efficacy was significantly ($p \leq 0.05$) influenced by WeedLock bioherbicide (Figure 2). However, the control efficacy was measured at 21 DAT and it was varied among the WeedLock application rates compared to control (untreated). The efficacy of WeedLock in the mixed-culture ranged from 86.24% to 98.49% as compared to untreated (control). T_3 (2691.00 L ha^{-1}) showed the highest weed control efficacy of 98.49%, followed by 98.15% and 86.24% for T_2 (1345.50 L ha^{-1}) and T_1 (672.75 L ha^{-1}) formulation, respectively. Overall, the T_2 (1345.50 L ha^{-1}) and T_3 (2691.00 L ha^{-1}) application rate exhibited excellent efficacy compared to T_1 (672.75 L ha^{-1}).

WEEDLOCK ACTIVITY IN DIFFERENT SOIL TEXTURES ON *Z. mays*

Data on the visual injury, plant height, leaf area, total chlorophyll content, root length, fresh weight, and dry weight of *Z. mays* were recorded to assess the soil activity of WeedLock in clay, sand, sandy clay loam, and peat soil. The soil activity of WeedLock in different soil types showed no significant influence on the observed parameters of *Z. mays* (Table 2). In all soil types, no injury symptoms of *Z. mays* were observed visually, and the injury scale rating was 1.00 (all leaves are green). In sandy clay loam soil, plant height was 111.43 cm for untreated (control) and 110.85 cm recorded for treated (WeedLock) and also no significant difference was observed. No significant difference was found in terms of leaf area, total chlorophyll content and root length of *Z. mays* in comparison to untreated (control) and treated trays. The highest leaf area and chlorophyll content were observed in peat soil over the other soil textures (clay, sand, and sandy clay loam).

The fresh weight of *Z. mays* in clay and sand soil was observed at 377.30 and 364.79 g in untreated (control) and 374.15 and 362.88 g in treated (WeedLock) trays, respectively. The dry weight of *Z. mays* in different soil textures was recorded in a different number. The dry weight in treated (WeedLock) soils was comparatively lower than the untreated (control) except for sand. WeedLock showed no significant effect in the increase (%) and decrease (%) in observed parameters of *Z. mays* in comparison with untreated on different soil textures.

WEEDLOCK ACTIVITY IN CLAY SOIL AT DIFFERENT WEEKS INTERVALS

WeedLock activity was observed in clay soil at different time intervals on germination, injury, plant height, fresh weight, and dry weight of *Z. mays*. All the parameters of *Z. mays* in treated (WeedLock) soil showed non-significant values when compared with untreated (control) (Table 3). No visual injury of *Z. mays* was observed at different week intervals. Plant height index was 69.92 to 75.60 cm in untreated (control) and 68.80 to 77.22 cm in WeedLock treated soil at different week intervals. Treated (WeedLock) soil did not show any considerable phytotoxic effect than untreated (control) in fresh weight and dry weight of *Z. mays*. Fresh weight and dry weight of untreated (control) plants were 143.46 to 155.53 g and 29.16 to 32.34 g, respectively; nevertheless, the plants grown in treated (WeedLock) soil were 142.08 to 154.08 g and 28.20 to 32.66 g respectively, for different week intervals.

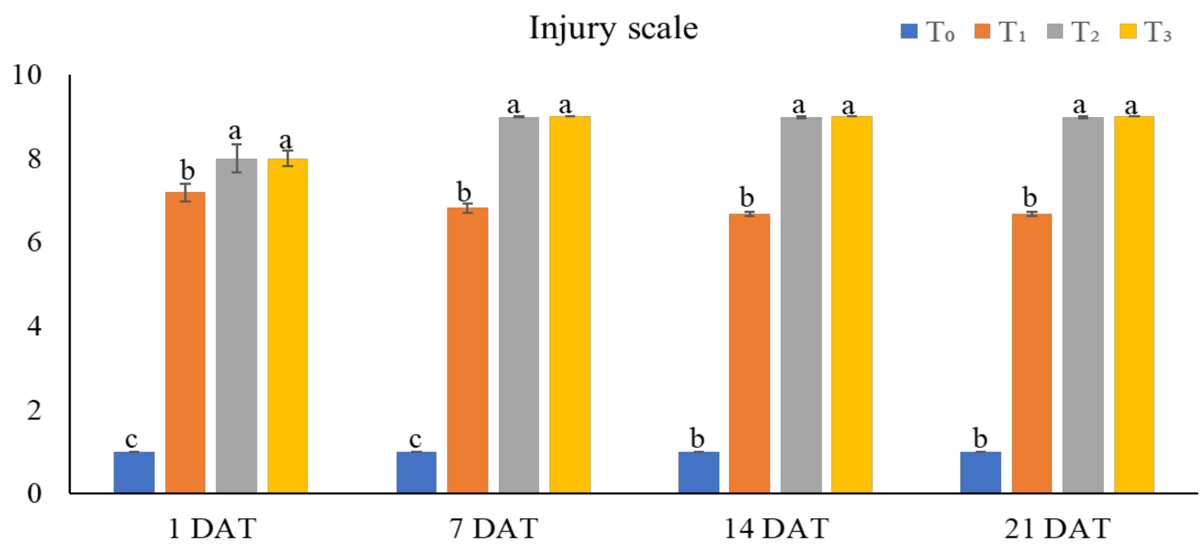

FIGURE 1. Injury rating scale after treated with WeedLock. Means having the same letter among the treatments are not significantly different at $p<0.05$. Here, T_0: untreated (control), T_1: 672.75 L ha^{-1}, T_2: 1345.50 L ha^{-1}, T_3: 2691.00 L ha^{-1}. DAT: Days after treatment

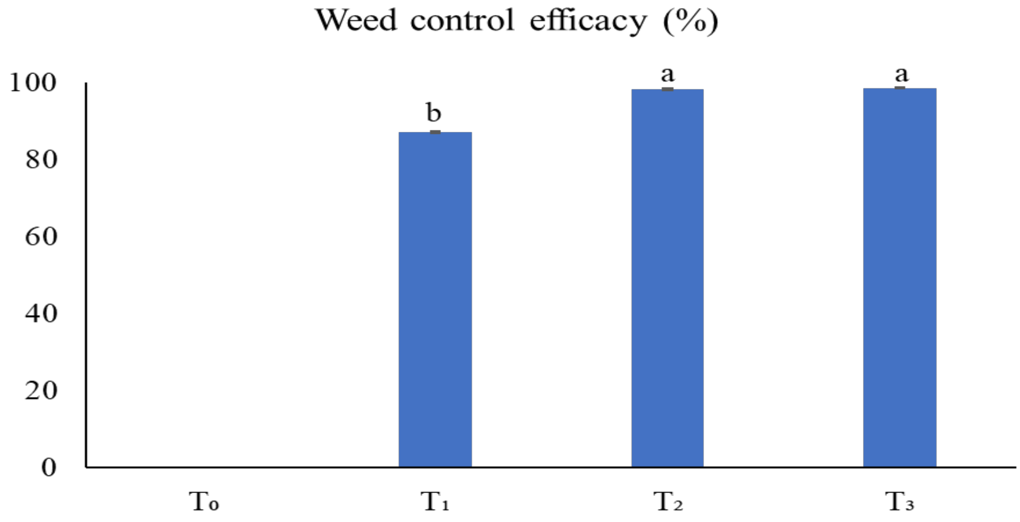

FIGURE 2. Weed control efficacy of WeedLock bioherbicide. Mean values sharing similar letters are considered not significant at p<0.05. Here, T_0: untreated (control), T_1: 672.75 L ha^{-1}, T_2: 1345.50 L ha^{-1}, T_3: 2691.00 L ha^{-1}

TABLE 2. Effect of soil activity of WeedLock on *Z. mays* in different tested soil textures

Soil types	Treatments	Injury (scale)	Plant height (cm)	Leaf area (cm^2)	Total chlorophyll (SPAD)	Root length (cm)	Fresh weight (g)	Dry weight (g)
Clay	Untreated	1.00a	110.73a	2531.42a	45.40a	41.44a	377.30a	61.66a
	WeedLock	1.00a	109.10a	2529.90b	44.51a	40.79a	374.15a	60.87a
Sand	Untreated	1.00a	106.13a	2529.85a	44.40a	39.66a	364.79a	57.68a
	WeedLock	1.00a	107.24a	2533.90a	45.26a	40.16a	362.88a	58.17a
Sandy clay loam	Untreated	1.00a	111.43a	2532.82a	46.07a	42.79a	385.75a	63.15a
	WeedLock	1.00a	110.85a	2531.19a	46.38a	42.22a	386.46a	62.97a
Peat	Untreated	1.00a	109.68a	2531.57a	46.51a	40.58a	370.34a	60.41a
	WeedLock	1.00a	110.07a	2533.44a	47.41a	39.97a	371.79a	59.83a

Mean values sharing similar letter for each soil type in the column are considered not significant at p<0.05

TABLE 3. Effect of WeedLock in clay soil *Z. mays*

Parameters	Treatments	Different weeks intervals					
		1	2	4	8	12	16
Germination (%)	Untreated	97.50a	97.50a	95.00a	97.50a	97.50a	97.50a
	WeedLock	100a	97.50a	92.50a	95.00a	100a	97.50a
Injury (scale)	Untreated	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
	WeedLock	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
Plant height (cm)	Untreated	74.05a	70.32a	72.16a	69.92a	75.60a	71.62a
	WeedLock	72.44a	71.02a	71.72a	68.80a	77.22a	71.50a
Fresh weight (g)	Untreated	147.99a	143.46a	155.35a	145.98a	152.92a	148.62a
	WeedLock	146.49a	142.08a	153.17a	144.78a	154.08a	148.99a
Dry weight (g)	Untreated	32.32a	29.16a	32.34a	30.42a	31.02a	30.76a
	WeedLock	31.03a	28.20a	32.66a	28.67a	32.60a	31.12a

Mean values sharing similar letter for each soil type in the column are considered not significant at $p<0.05$

WEEDLOCK ACTIVITY IN SAND AT DIFFERENT WEEKS INTERVALS

WeedLock activity on the sand on the germination and growth components of *Z. mays* was presented in Table 4. It showed no significant effect on the observed parameters at different weeks intervals. At 1-week interval, germination of *Z. mays* was 97.50% for untreated (control) and 100% for treated (WeedLock) trays. Untreated (control) trays, plant height was 69.05 cm and 67.17 cm for treated (WeedLock) trays at 1 week interval. The plant height of *Z. mays* treated (WeedLock) in the sand was higher than untreated (control) at 2 and 12 weeks intervals. A similar pattern was also found in the dry weight of *Z. mays* at 2 and 8 weeks intervals. At 1 to 16 weeks intervals, the fresh weight of *Z. mays* was observed 141.73 g to 150.30 g in untreated (control) and 145.05 to 149.22 g in treated (WeedLock) trays, respectively.

TABLE 4. Effect of WeedLock in sand on *Z. mays*

Parameters	Treatments	Different weeks intervals					
		1	2	4	8	12	16
Germination (%)	Untreated	97.50a	95.00a	100a	97.50a	97.50a	100a
	WeedLock	100.00a	95.00a	97.50a	100a	95.00a	97.50a
Injury (scale)	Untreated	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
	WeedLock	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
Plant height (cm)	Untreated	69.05a	66.55a	70.17a	68.20a	68.50a	67.70a
	WeedLock	67.17a	67.82a	69.75a	67.92a	69.40a	68.32a
Fresh weight (g)	Untreated	144.68a	141.73a	146.02a	145.14a	150.30a	146.85a
	WeedLock	143.81a	140.89a	145.15a	145.05a	149.22a	146.24a
Dry weight (g)	Untreated	29.59a	27.46a	29.31a	29.90a	30.21a	29.70a
	WeedLock	28.86a	27.92a	28.19a	30.18a	29.55a	28.91a

Mean values sharing similar letter for each week in the column are considered not significant at $p<0.05$

WEEDLOCK ACTIVITY IN SANDY CLAY LOAM SOIL AT DIFFERENT WEEKS INTERVALS

All the experimental parameters of *Z. mays* showed similarity in their sensitivity to the WeedLock in sandy clay loam soil. The effects on germination and visual injury scale of *Z. mays* were non-significant and consistent for all untreated (control) and treated (WeedLock) trays at 1 to 16 weeks intervals (Table 5). A similar effect was also observed on the plant height for all week intervals. At 16 weeks, plant height was 72.20 cm for untreated (control) soil; in contrast, 71.90 cm were calculated from treated (WeedLock) soil. The dry biomass at different week intervals of the treated (WeedLock) sandy clay loam soil was insignificant compared to untreated (control). At 1 and 16 weeks intervals, the dry weight of *Z. mays* was 151.08 and 149.73 g for untreated (control), and 149.97 and 150.12 g were observed for *Z. mays* grown in treated (WeedLock) soil.

WEEDLOCK ACTIVITY IN PEAT SOIL AT DIFFERENT WEEKS INTERVALS

The incorporation of WeedLock in peat soil provided a non-significant effect on germination, injury, plant height, fresh weight, and dry biomass of *Z. mays* (Table 6). In all week intervals, the germination percentage of *Z. mays* in peat soil was ranged from 95 to 100% for both untreated (control) and treated (WeedLock) peat soil. At 1 week interval, in peat soil, plant height of *Z. mays* was 75.19 cm for untreated (control), and 73.63 cm was recorded for treated (WeedLock) soil, and 75.85 and 77.07 cm were observed at 16 weeks interval in untreated (control) and treated (WeedLock) soil, respectively. Compared to untreated (control), the decrease or increase percentage in fresh weight and dry weight of *Z. mays* in treated (WeedLock) peat soil also indicated that they were not affected by the residue of WeedLock.

TABLE 5. Effect of WeedLock in sandy clay loam on *Z. mays*

Parameters	Treatments	Different weeks intervals					
		1	2	4	8	12	16
Germination (%)	Untreated	100a	95.00a	100a	97.50a	97.50a	97.50a
	WeedLock	97.50a	97.50a	97.50a	95.00a	100a	95.00a
Injury (scale)	Untreated	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
	WeedLock	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
Plant height (cm)	Untreated	73.27a	71.12a	71.80a	74.10a	71.22a	72.20a
	WeedLock	74.45a	70.65a	71.52a	73.35a	72.07a	71.90a
Fresh weight (g)	Untreated	151.08a	145.05a	150.11a	151.31a	153.74a	149.73a
	WeedLock	149.97a	145.30a	148.91a	151.20a	153.47a	150.12a
Dry weight (g)	Untreated	31.79a	30.11a	31.46a	31.76a	32.39a	30.44a
	WeedLock	32.27a	28.71a	30.96a	30.65a	32.20a	30.44a

Mean values sharing similar letter for each week in the column are considered not significant at $p<0.05$

DISCUSSION

The use of agrochemicals in the agricultural system to control weeds and other pests has increased dramatically in recent years. The increased public interest for safe 'green' herbicides has resulted in the development of several new bioherbicides for weed management. For example, WeedLock is a commercial bioherbicide derived from plant extract and showed a promising weed control efficacy (Hasan et al. 2021). WeedLock possesses excellent efficacy on weeds by causing significant injury.

An injury symptom, such as chlorosis, growth stunting, and burn-down, followed by death, was evident. Moreover, WeedLock at lower/half rate, showed low to moderate injury symptoms while complete killed was observed in recommended rate (T_2) and higher rate (T_3). WeedLock efficacy increased with increasing application rate. Similarly, increasing the extract concentration of *Parthenium hysterophorus L.*, *Cleome rutidosperma* DC., and *Borreria alata* (Aubl.) DC. showed excellent efficacy on *A. conyzoides* and *Euphorbia hirta* L. (Motmainna et al. 2021).

In the present study, WeedLock did not affect the germination of *Z. mays*. *Z. mays* showed similarity in their sensitivity to WeedLock residue in different tested soil textures. The reason behind this is maybe WeedLock bioherbicide deactivated quickly in the soil that's why showed no soil activity. WeedLock may be broken down or adsorbed tightly to soil particles, making it less accessible to growing plants. A similar mechanism was addressed by Wibawa et al. (2009), where recommended rates of paraquat, *glyphosate isopropyl-amine,* and glufosinate-ammonium had no residual effects on soil that resulted in no phytotoxicity to *Z. mays* and *Cucumis sativus* L. WeedLock had a consistent effect on *Z. mays* seedling growth and development for clay, sand, sandy clay loam, and peat soil at 21 days after application. WeedLock was soil-drenched at 1345.50 L ha^{-1} (recommended rate) in different soil types, and the effect did not show any significant decrease in germination, growth, and development of *Z. mays*. The injury rating scale was 1.00 for *Z. mays* meaning that all leaves of *Z. mays* were green and the plant was actively growing on the WeedLock treated soil. In addition, *Z. mays* may not receive any phytotoxic effects from the treated (WeedLock) soil textures at 1, 2, 4, 8, 12, and 16 weeks after the first harvest. Bailey (2014) mentioned that the environmental fate of registered bioherbicides is usually short, thus resulting in lower exposure.

Some researchers found that organic herbicides have no residual activity, but they killed growing weeds when applied as post-emergence (Wilen 2012). The concentration of allelochemicals in soils can be reduced by leaching, microbial breakdown, uptake by plants, and physiological processes (Sangeetha et al. 2015). Allelochemicals bind with clays, and soil's organic matter makes it unavailable to cause phytotoxic effects in indicator plants. The unavailability of phytotoxic compounds exudates from plants is occurred by the sorption and oxidation (Bhowmik 2018).

Different soil textures influence the leaching of phytotoxic compounds directly (Real et al. 2019). Many researchers found a different inhibitory effect of plant extracts in different soil textures. Some scientists claimed higher inhibitory effect on clay soil while others found in the sandy substrate and so on (Bouhaouel et al. 2018; El-Darier et al. 2014). In our present study, we investigated the phytotoxic effect of WeedLock in clay, sand, sandy clay loam, and peat soil to observe the phytotoxic level on *Z. mays* as an indicator plant. But we did not get any soil activity or residual effect of WeedLock on growth components of *Z. mays*. Since WeedLock is a post-emergence contact bioherbicide, the chances of their effect on germination should be very low or negligible. To be sure, if there are phytotoxic residues of WeedLock present in the applied soils, it influences the germination of *Z. mays* and also impacts the growth and morphological characteristics of *Z. mays*.

TABLE 6. Effect of WeedLock in peat soil on *Z. mays*

Parameters	Treatments	Different weeks intervals					
		1	2	4	8	12	16
Germination (%)	Untreated	97.50a	100a	97.50a	97.50a	95.00a	97.50a
	WeedLock	95.00a	97.50a	97.50a	100a	97.50a	100a
Injury (scale)	Untreated	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
	WeedLock	1.00a	1.00a	1.00a	1.00a	1.00a	1.00a
Plant height (cm)	Untreated	75.19a	72.07a	74.37a	72.62a	74.15a	75.85a
	WeedLock	73.63a	71.05a	75.07a	71.52a	73.22a	77.07a
Fresh weight (g)	Untreated	151.34a	146.49a	156.89a	147.48a	154.98a	155.23a
	WeedLock	151.98a	145.21a	155.78a	146.22a	155.24a	156.04a
Dry weight (g)	Untreated	32.16a	29.57a	33.49a	30.90a	32.98a	32.62a
	WeedLock	31.61a	30.05a	32.98a	30.67a	33.09a	32.95a

Mean values sharing similar letter for each week in the column are considered not significant at $p<0.05$

Conclusion

Our present study observed that WeedLock bioherbicide at the recommended rate showed excellent weed control efficacy on tested weeds and exhibited no soil activity on different soil textural conditions; thus, no phytotoxicity was observed in *Z. mays*. However, the potential environmental risk connected with WeedLock would be minimal due to low soil activity. Hence, it can be used as a safer and greener weed management tool in sustainable agriculture. Moving forward, the impact of WeedLock on soil's microbial community should be identified.

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