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Effect of surfactant and different spray volumes on the efficacy of acetic acid based natural herbicide for controlling *Imperata cylindrica* and *Sporobolus indicus*

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Abstract

Weed-out^{TM} is a contact post-emergence herbicide that contains the active component acetic acid. Our prior research showed that it was ineffective against grassy weeds with thick cuticle, small, and upright leaves. This study aims to determine different spray volumes of Weed-out^{TM} applied with or without surfactant for controlling grassy weeds *Imperata cylindrica* and *Sporobolus indicus* in a ten-year-old mango farm. At the inter rows of mango trees, Weed-out^{TM} was applied at spray volumes of 0, 2000, 4000, 6000, and 8000 L/ha with or without non-ionic surfactant (NIS). The efficacy of each treatment was assessed based on percentage of weed killed (0 to 100%) weekly for one month. Weed-out^{TM} combined with NIS did not significantly increase weed control ($p<0.05$). After one week of treatment (WAT), application of Weed-out^{TM} at 6000 and 8000 L/ha spray volumes produced excellent control (93-100 %) of *I. cylindrica* and *S. indicus*. At 4 WAT, the spray volumes still provided adequate weed control, although control was reduced to 63-75 %. At 1 WAT, Weed-out^{TM} applied at 2000 and 4000 L/ha produced 75-91 % control of the weeds, but at 4 WAT, the efficacy of Weed-out^{TM} was reduced to 22-56 % control. When Weed-out^{TM} was applied at 2000 L/ha, *S. indicus* regrew at 3 WAT, but *I. cylindrica* recovered at 2 WAT. These findings suggested that application of Weed-out^{TM} at 6000 and 8000 L/ha without NIS could effectively control *I. cylindrica* and *S. indicus* within 4 weeks.

Keywords: Grass weeds; mango; non-ionic surfactant; post-emergence.
Abbreviation: WAT_ week after treatment

Introduction

Acetic acid has been shown to have antibacterial, herbicidal, and nematicidal properties (Aguirre et al., 2020; Ntalli et al. 2021; Park et al. 2021). It can be used as a contact herbicide to kill weeds by destroying their leaf tissues, resulting in quick elimination (Webber et al., 2018). Several investigations on the potential of acetic acid for weed management on land (Domenghini, 2020; Liu et al, 2021) and in water (Gettys, et al, 2021) have been done. For example, Domenghini (2020) found that applying 20% and 30 % acetic acid to an organic vegetable garden required three to four retreatments to provide satisfactory weed control.

The quantity of herbicide droplets produced and how thoroughly the herbicide covers the target are determined by the spray volume. For efficient target coverage, larger canopies and stubble loads always necessitate higher application volumes (Gordon, 2013). Contact herbicides, such as acetic acid, provide quick control but require more weed coverage and application volume than systemic herbicides for best performance. Evan and Bellinder (2009) reported that weed control was highest (83 %) across all test weeds when vinegar containing 20% acetic acid was sprayed at 636 L/ha, while weed control decreased to 62 % when the same treatment was applied at 318 L/ha. A recent study by Liu et al (2021) revealed that wood vinegar with acetic acid as main constituent applied at 4000 L/ha showed varying levels of control for broadleaf weeds of *Perilla frutescens* (L.) Britt., *Oxalis corniculata* L., and *Geranium carolinianum* L. ranging from 82 to 100% under field conditions. However, there is still limited study on efficacy of acetic acid for grassy weed control (Webber et al., 2018).

Surfactant is a specialized addition intended to increase the herbicide's efficiency in the spray solution (Miller and Westra, 2008). For post-emergence herbicides, it is the most extensively used adjuvant. Surfactant improves herbicide efficacy by altering one or more spray solution properties, such as dispersion and wetting on leaf surfaces, as well as adhesion and penetrating characteristics to leaf surfaces (Bell et al., 2019). Weed-out™ is registered as a natural contact herbicide that contains a blend of acetic acid (20%), amino acid and macro nutrients. The herbicide kills only parts of the plant where it contacts; it does not provide good control of grassy weeds because of thick cuticle, narrow and upright leaves. As a result, the grassy weeds can recover in a short period. To improve the herbicidal action of Weed-out^{TM} for grassy weed control, a proper spray volume with surfactant is required. Thus, this study aims to examine the effects of different spraying volumes of Weed-out™ added with or without non-ionic surfactant for controlling grassy weeds of *Imperata cylindrica* and *Sporobolus indicus.*

Results and Discussion

Response of Imperata cylindrica to Weed-out™

Two-way ANOVA revealed no significant interaction between the spray volume of Weed-out™ and the presence of surfactant on weed control. The data were pooled, and the main effects of spray volume (Table 4) and the presence of non-ionic surfactant (Table 5) are presented. Table 5 shows that treated plots' weeds turned brownish colour one week after treatment (WAT). When averaged across surfactant, spray volumes at 6000 and 8000 L/ha of Weed-out™ had excellent control of *Imperata cylindrica* ranging from 93-95% compared to 4000 L/ha which provided 87% control while 2000 L/ha gave 75 % of weed control.

At 2 WAT, the efficacy of Weed-out™ treatments dropped slightly, but the treatment of 4000, 6000 and 8000 L/ha showed comparable weed control ranging from 75 to 90% control. Also, 6000 and 8000 L/ha recorded better control of *I. cylindrica* as compared to 2000 L/ha. At 3 WAT and thereafter, each treatment's efficacy decreased, but control of *I. cylindrica* exhibited by 6000 and 8000 L/ha Weed-out™ remained very good (72-77%) whereas 2000 and 4000 L/ha Weed-out™ exhibited deficient to moderate control (33 to 45%). At 4 WAT, the control of each treatment further decreased, with 2000 and 4000 L/ha Weed-out™ having deficient control (22-32%). By contrast, 6000 and 8000 L/ha Weed-out™ still provided good control of weed (63-65%).

The efficacy of Weed-out™ treatments to control *I. cylindrica* gradually decreased. *Imperata cylindrica* is a perennial grass with rhizomes as a reproduction system, and it can grow up to 1.2 m high. It has hardened, ramified and rhizomatous roots that explore soil layers to 60 cm (Heuze et al., 2017). The quick growth of the rhizome above ground is enhanced by mowing, fire or unsatisfactory treatment with herbicides. Rhizomes should be eradicated, and no live parts must be left to achieve a complete kill. The challenge of *I. cylindrica* eradication is expected to increase with the infestation as the rhizome mat's density and depth increase (Minogue et al., 2012).

Table 5 presents the main effect of a non-ionic surfactant on control of *I. cylindrica* within one month after Weed-out™ treatment. It is found that the presence of surfactant had no significant effect on control of *I. cylindrica* when averaged across spray volume, indicating that the addition of surfactant failed to enhance the efficacy of Weed-out™ on control of *I. cylindrica* irrespective of any week after treatment. Webber and Shrefler (2007) conducted a study to evaluate the interaction effects between vinegar spray volume and surfactants on weed control. The results showed that vinegar controlled broadleaved weeds better than those grassy weeds. However, surfactants such as orange oil and canola oil did not increase the efficacy of vinegar when averaged across spraying volume.

Response of Sporobolus indicus to Weed-out™

Table 6 presents the main effect of spray volume on control of *S. indicus* throughout four weeks of the experimental period. Spray volumes of 6000 and 8000 L/ha Weed-out™ gave excellent control of *S.indicus* ranging from 98-100%, whereas 2000 L/ha provided 87% control, and 4000 L/ha Weed-out™ gave 91% weed control at 1 WAT when averaged across surfactant.

At 2 WAT, the efficacy of 2000 L/ha dropped to 78% control, but the treatment of 4000, 6000, and 8000 L/ha showed comparable *S.indicus* control at 85, 90 and 95%, respectively. Besides, 6000 and 8000 L/ha Weed-out™ recorded better control of *S. indicus* compared to 2000 L/ha Weed-out™.

At 3 WAT, each treatment's efficacy decreased, but control of *S. indicus* given by 4000, 6000, and 8000 L/ha Weed-out™ remained very good (70-86%) while 2000 L/ha showed moderate control (57%). At 4 WAT, all treated plots' efficacy continued to decrease, with 2000 and 4000 L/ha giving moderate control. On the other hand, 6000 and 8000, L/ha Weed-out™ still showed good to very good control of weed (68-76%). The control of *S. indicus* at 1 WAT decreased from 100% to 76% at 4 weeks after treatment. The reduced control was due to the regrowth of the weed in the plot.

Based on Table 7, the presence of non-ionic surfactant did not increase the efficiency of all treatments within one month after treatment when averaged across spray volume. There was no significant difference between the treatments, whether it was added with or without non-ionic surfactant. Hartzler (2020) stated that the suitable use of surfactants is a crucial step towards effective weed control. Meanwhile, decreased rates of herbicides can also produce an acceptable outcome. One surfactant's effectiveness is based on timely implementation and knowledge of targeted weed susceptibility, and it is not influenced by whether the surfactant is more effective than other types of adjuvant.

Evan et al (2011) reported that 200-grain vinegar containing 20% acetic acid applied at 700 L/ha have potential for in-row weed control of vegetables. High levels of weed control at early post treatment imply that there is merit to using vinegar in-row relative to hand weeding or hoeing. On the other hand, a previous study by Abouziena et al. (2009) demonstrated that 30% acetic acid provided excellent control of grassy weeds such as *Setaria viridis* (L.) Beauv., *Lolium multiflorum* Lam., *Sorghum halepense* (L.) Pers at 4 WAT when applied early post treatment with a spray volume of 197 L/ha. By contrast, application of 30% acetic acid at late post treatment, the efficacy decreased drastically. Another study by Evan and Belinder (2009) showed that when *Digitaria sanguinalis* (L.) Scop were small, grain vinegar (20% acetic acid) applied at 636 L/ha gave the greatest control (91%) and biomass reduction (93%). However, when the same treatment was applied to weeds with more than six leaves, the control was reduced by 14 % and the biomass increased by 38 %.

Similarly, late post treatments of Weed-out™ at low spray volume of 2000 L/ha failed to control *I. cylindrica* and *S. indicus* effectively at 4 WAT because these test weeds were more than 40 cm in height at vegetative and flowing stages. It is interesting to note that increasing the spray volume from 2000 to 8000 L/ha could increase the efficacy of Weed-out™ for controlling *I. cylindrica* and *S. indicus*. Adequate application volume appears to be critical for maximizing weed control with Weed-out™. In agreement with the present study's findings, Liu et al (2021) documented that wood vinegar with acetic acid as main constituent provided 76 % biomass reduction in *P. frutescens* at 7 days after treatment at a spray volume of at 4000 L/ha in growth chamber. Meanwhile, a 2000 L/ha application volume caused 60 % biomass reduction in *P. frutescens*. The efficacy of application volumes of 1000 or 2000 L/ha was significantly lower. Webber et al. (2018) also reported the increased

Table 1. Average meteorological data from October to December 2020 on Harumanis mango farm.

Month	Rainfall (mm)	Number of rain days (days)	24 Hour Temperature Mean (°C)
October	265.2	20	26.7
November	293.4	20	26.8
December	149.0	13	26.6

Table 2. List of treatments.

No	Treatment
1	0 L/ha (without surfactant)
2	2000 L/ha without surfactant
3	4000 L/ha without surfactant
4	6000 L/ha without surfactant
5	8000 L/ha without surfactant
6	0 L/ha (with surfactant)
7	2000 L/ha with surfactant
8	4000 L/ha with surfactant
9	6000 L/ha with surfactant
10	8000 L/ha with surfactant

Table 3. Visual score and percentage of grass weed control.

Score	Efficacy (weed kill)	Weed control (%)
0	No injury	0
1 2	Poor Poor	1-9 10-19
3	Deficient	20-29
4	Deficient	30-39
5	Moderate	40-49
6	Moderate	50-59
7	Good	60-69
7	Very good	70-89
8	Excellent	90-99
9	Complete kill	100

Table 4. Main effect of Weed-out™ spray volume on control of *Imperata cylindrica* within one month after treatment.

	Time after treatment (week)			
Spray volume (L/ha)	1	2	3	4
	Weed Control (%)			
0	0^{a}	0^{a}	0^{a}	0^{a}
2000	75^{b}	58^{b}	33^{b}	22^{ab}
4000	87^{bc}	75^{bc}	45^{b}	32^{b}
6000	93^{c}	87^{c}	72^{c}	63^{c}
8000	95^{c}	87^{c}	77^{c}	65^{c}

The main effect within the same column, followed by the same letter, indicates no significant difference at P ≥0.05 as determined by the Tukey test. Visual score 0 denotes no-kill symptom (0 % weed control) while 100 denotes plant death or completely scorched (100% weed control).

Table 5. Main effect of a non-ionic surfactant on control of *Imperata cylindrica* within one month after Weed-out™ treatment.

	Time after treatment (week)			
Presence of surfactant	1	2	3	4
	Weed Control (%)			
With	69^{a}	61^{a}	43^{a}	34^{a}
Without	70^{a}	61^{a}	47^{a}	39^{a}

The main effect within the same column followed by the same letter indicates no significant difference at P ≥0.05 as determined by the independent T-test. Visual score 0 denotes no-kill symptom (0 % weed control) while 100 denotes plant death or completely scorched (100% weed control).

Table 6. Main effect of Weed-out™ spray volume on control of *Sporobolus indicus* within one month after treatment.

	Time after treatment (week)			
Spray volume (L/ha)	1	2	3	4
	Weed Control (%)			
0	0[a]	0[a]	0[a]	0[a]
2000	87[b]	78[b]	57[b]	48[b]
4000	91[bc]	85[bc]	70[b]	56[b]
6000	98[c]	90[cd]	78[cd]	68[c]
8000	10[c]	95[d]	86[d]	76[c]

The main effect within the same column followed by the same letter indicates no significant difference at P ≥0.05 as determined by the Tukey test. Visual score 0 denotes no-kill symptom (0 % weed control) while 100 denotes plant death or completely scorched (100% weed control).

Table 7. Main effect of surfactant on control of *Sporobolus indicus* within one month after Weed-out™ treatment.

	Time after treatment (week)			
Presence of surfactant	1	2	3	4
	Weed Control (%)			
With	74[a]	68[a]	57[a]	48[a]
Without	76[a]	7[a]	59[a]	51[a]

The main effect within the same column followed by the same letter indicates no significant difference at P ≥0.05 as determined by the independent T-test. Visual score 0 denotes no-kill symptom (0 % weed control) while 100 denotes plant death or completely scorched (100% weed control).

spray volume of acetic acid from 187 to 935 L/ha could enhance the control efficiency of *D. sanguinalis*.

Weed-out™ at a spray volume of 8000 L/ha can provide 65-100% weed control depending on the targeted weed species. It is found that this treatment gave excellent weed control within 2 WAT but the efficacy reduced thereafter. Webber et al. (2018) recorded that natural contact herbicide containing acetic acid or vinegar was more effective in controlling broadleaf weeds than grassy type weed species but the grassy weed control was decreased starting from 3 WAT. The addition of non-ionic surfactant did not increase the efficiency of Weed-out™. Treatment of 8000 L/ha with surfactant was unable to control *I. cylindrica* completely 3 to 4 WAT. Besides, environmental factors such as rainfall or precipitation also can affect the efficacy of natural contact herbicide such as Weed-out™. Renz (2016) stated that herbicide absorption is greatly affected by spray droplets' movement on the foliar area when the application of herbicide is followed by rainfall afterwards because spray droplets appear to get removed easily from the wet surface of leaves. The reduced efficacy of Weed-out™ 3 and 4 WAT in the present study is most likely due to rainy day after treatment (Table 1).

Materials and methods

Experimental site

The study was conducted at Harumanis mango plot of UiTM Arau, Perlis, with the coordinate of (6º45'56.''N 100º27'.66''E) from October to December 2020. The variety of Harumanis mango is MA128. The trees have been planted since 2010 at a planting distance of 9 m x 9 m between rows. Temperatures and rainfall of the experimental site are stated in Table 1.

Herbicides and surfactant

The surfactant used in this study is Speed-Thru®. It is a non-ionic surfactant that contains octylphenoxypolyethoxy-etanol, alkyl ester sulfonate and isopropanol. The natural contact herbicide examined is Weed-out™. This product is provided by CJ BIO (Malaysia) Sdn. Bhd. It contains a blend of acetic acid (20%), amino acid and macro nutrients.

Field experiment

There were 30 plots where each plot measuring 10 m² (2 m x 5 m) was established using bamboo sticks and raffia rope. Then, a series of spraying volumes, *viz* 0, 2000, 4000, 6000 and 8000 L/ha mixed with or without surfactant, were applied at plots established at the inter-row areas of Harumanis mango using a conventional knapsack sprayer with a flat fan nozzle. There are ten treatments with three replicates in this experiment (Table 2). The treatments were arranged as 5 x 2 factorial in a complete randomised block design where factor one is spraying volume, whereas factor two is the presence of surfactant. The weed assessment was carried out based on visual estimation kill on two selected grassy weed species of *Imperata cylindrica* (L.) Raeusch. and *Sporobolus indicus* (L.) R.Br weekly after each treatment for one month. These weedy plants were about 45 cm in height at the vegetative and flowering stages. The rating was given based on the visual score and percentage of weed kill based on the method of Dear et al. (2003) with modification. The rating was 0% if there is no kill symptom on the target weed and 100% if the weed has been completely killed as shown in Table 3.

Statistical analysis

The percentage data of weed control were checked for normality and homogeneity of variance before subjected to two-way ANOVA, and the differences between mean were compared using Tukey's Honestly Least Significance Differences (HSD) (p≤0.05).

Conclusion

In summary, the addition of non-ionic surfactant did not improve the weed control efficacy for all Weed-out™ treatments regardless of any weed species. However, the results showed that Weed-out™ at 8000 L/ha of spray volume could provide 65-100% weed control depending on targeted weed species within one month of assessment. *Sporobolus indicus* was found to be more susceptible to Weed-out™ as compared to *I. cylindrica.* Future studies are needed to evaluate the efficiency of Weed-out™ by adding different types of surfactants to enhance the performance of Weed-out™. Besides, a series dosage of surfactant should be examined on the efficacy of Weed-out™ for weed control.

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