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*Full Length Article*

# Effectiveness of Acetic Acid-Based Natural Herbicide Combined with Glufosinate for Annual Broadleaf Weed Control

**T.S. Chuah [1*], Z. Nurul Syafiqah[1], B.W. Lee[2], A. Muhammad Firdaus[2] and S.S. Lim[2]**
[1]*Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Perlis Branch 02600 Arau, Perlis, Malaysia*
[2]*CJ Bio Malaysia Sdn. Bhd, Lot Q, Bio Polymer Park, Phase 2, Mukim Kerteh, 24300 Kerteh, Malaysia*
[*]For correspondence: chuahts@uitm.edu.my
[†]Contributed equally to this work and are co-first authors
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## Abstract

WeeMover® is a post-emergence natural contact herbicide with acetic acid as its active ingredient. Previous research indicated that effective weed control requires 6000 to 8000 L/ha of WeeMover®. However, the high volume of spraying could result in increased labor costs. Therefore, this study aimed to assess the efficacy of WeeMover® combined with glufosinate at a lower spraying volume for selected weeds in mature mango fields under field conditions. Field trials were conducted at the Farm unit of UiTM, Perlis, during the rainy season. Using a knapsack sprayer, various treatments, including glufosinate at a recommended rate of 495 g ai/ha, WeeMover® alone and WeeMover® combined with glufosinate at 124 or 248 g ai/ha, were applied at a spraying volume of 450 L/ha. Three annual broadleaved weed species—*Ageratum conyzoides* L., *Euphorbia hirta* L. and *Borreria latifolia* (Aubl.) K. Schum were visually assessed weekly for one-month post-treatment based on the percentage of weeds killed. The results revealed that the combination of WeeMover® and glufosinate at 248 g ai/ha was as effective as glufosinate alone at 495 g ai/ha for controlling the test weeds. The combination treatment provided excellent control (90–100%) of the test weeds throughout the four-week evaluation period. These findings suggest that the recommended rate of glufosinate can be halved when mixed with WeeMover® to achieve outstanding control of annual broadleaf weeds.

**Keywords:** *Ageratum conyzoides*; *Borreria latifolia*; *Euphorbia hirta*; Herbicide; Mango; Tank mixture

## Introduction

Acetic acid is renowned for its herbicidal, antibacterial and nematocidal properties (Aguirre *et al.* 2020; Ntalli *et al.* 2021; Park *et al.* 2021). As a contact herbicide, it targets weeds by destroying their cell membranes, leading to the desiccation and death of plant tissue (Webber *et al.* 2018). This herbicidal action is fast but less effective against grassy weeds that have thick cuticles and small, upright leaves (Chuah *et al.* 2022). Extensive research has highlighted the potential of acetic acid for weed management on both land (Domenghini, 2020) and in aquatic environments (Gettys *et al.* 2021). For instance, Domenghini (2020) found that applying 20 to 30% acetic acid in an organic vegetable garden required three to four reapplications to achieve satisfactory weed control. Additionally, broadleaf weeds like carpetweed (*Mollugo verticillata* L.) and cutleaf evening primrose (*Oenothera laciniata* Hill) were successfully eradicated with 20% acetic acid at application rates of 181 or 909 L/ha (Webber *et al.* 2018).

A recent study by Chuah *et al.* (2022) demonstrated that the application of WeeMover®, an acetic acid-based herbicide, at spray volumes of 6000 and 8000 L/ha, achieved excellent weed control one week after treatment (WAT). By 4 WAT, the control remained adequate, though reduced to 63–75%. However, the high labor costs and expense of the herbicide at such high volumes pose practical challenges (Liu *et al.* 2021). This necessitates reducing the spraying volume without compromising efficacy, potentially by combining acetic acid with commercial herbicides like glufosinate. Glufosinate is a broad-spectrum, contact post-emergence herbicide widely used in vegetable farms and orchards (DOA 2024). It works by inhibiting glutamine synthase in plants (Shaner 2014). Numerous studies have explored tank mixtures of glufosinate with other herbicides, such as clethodim (Meyer *et al.* 2021), metribuzin (Dilliott *et al.* 2022) and dicamba (Priess *et al.* 2022). These interactions have ranged from synergistic (Takano *et al.* 2020) to additive (Jones *et al.* 2022) or antagonistic (Chuah *et al.* 2008), depending on the herbicides used. Research on the combination of acetic acid with other substances has shown mixed results. For

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example, adding orange oil did not enhance weed control efficacy (Webber *et al.* 2018). However, limited research has focused on the efficacy of acetic acid-based herbicides when tank-mixed with glufosinate.

Three annual broadleaved weeds of billy goat weed (*Ageratum conyzoides* L.), garden spurge (*Euphorbia hirta* L.) and buttonweed (*Borreria latifolia* (Aubl.) K. Schum) were examined in this study for their invasiveness and high abundance in mango cultivation. Although specific data on the yield loss of mango due to these weeds are limited, they have been reported to impact other crops. For instance, *B. latifolia* reduced the dry weight and height of young rubber by 12 and 17%, respectively (Chee 1994). Different *Euphorbia* species caused yield reductions of 4–85% in field crops, depending on occurrence densities (Tanveer *et al.* 2013). Additionally, the seedling length and dry weight of rice were significantly reduced by 16–20% in soil from *A. conyzoides*-infested fields compared to soil from weed-free areas (Batish *et al.* 2008). This study aimed to evaluate the efficacy of WeeMover® combined with glufosinate against *A. conyzoides*, *E. hirta* and *B. latifolia* at a lower spraying volume of 450 L/ha.

## Materials and Methods

### Experimental site

The research took place at a mango orchard within UiTM Arau, Perlis, situated at coordinates (6º45'56."N 100º27'.66"E) from August to September 2022. The mango variety cultivated is MA128, with trees planted since 2015 at intervals of 9 m by 9 m between rows. The soil composition comprises loamy sand with the following proportions: sand (53%), silt (33%) and clay (14%). The pH level of the soil is 6.2, with an organic matter content of 2.9% and a cation exchange capacity of 9.5 meq/100 g.

### Herbicides

WeeMover®, a natural contact herbicide, was the subject of examination. The product is ready-to-use in concentration without dilution or added to a carrier. This product, supplied by CJ BIO (Malaysia) Sdn. Bhd., contains a combination of acetic acid (20%), amino acids and macronutrients. The commercial herbicide glufosinate was purchased from a pesticide outlet in Arau, Perlis.

### Field experiments

Circular plots, each measuring 12.6 square m with a diameter of 4 m, were established under the canopy of mango trees. These plots received sunlight exposure with shade levels below 30%. *Ageratum conyzoides*, *Euphorbia hirta* and *Borreria latifolia* plants, ranging from 10 to 25 centim in height at the vegetative and flowering stages, were treated using a conventional knapsack sprayer equipped with a 5/64-inch fan jet nozzle, achieving a spraying volume of 450 L/ha. Weekly rainfall data during the experiment period were collected from a nearby meteorological station, with temperatures of 25 to 32°C and rainfalls ranging from 160 to 180 millim starting from one week before herbicide treatment until four weeks after herbicide treatment. The experiment was laid out in a randomized completely block design, comprising four different herbicide treatments (Table 1) and one weedy check, with six replications. Weed control efficacy was evaluated weekly for four weeks using a visual scoring system ranging from 0% (no scorching symptoms) to 100% (complete plant death), following the method outlined by Dear *et al.* (2003).

### Statistical analysis

Percentage data related to weed control underwent checks for normality and homogeneity of variance before being subjected to one-way ANOVA. Mean differences were compared using Tukey's Honestly Least Significant Differences (HSD) at a 5% significance level using SPSS version 25 for Windows, SPSS Inc., 233 South Wacker Dr. Chicago, IL 60606.

## Results

### Ageratum conyzoides

Table 2 presents the efficacy of WeeMover®, glufosinate and their combinations in controlling *Ageratum conyzoides* under the mango canopy at one, two, three and four weeks post-application. Despite the field test being conducted during the rainy season, all treatments demonstrated remarkable weed control (80 to 93%) during the initial two weeks following application. WeeMover®+ glufosinate at 248 g ai/ha exhibited greater efficacy ($P < 0.05$) than WeeMover® alone or in combination with glufosinate at 124 g ai/ha for weed control starting from week three onwards. Over the four-week evaluation period, the weed control effectiveness of WeeMover® + glufosinate at 248 g ai/ha remained comparable ($P > 0.05$) to that of glufosinate at 495 g ai/ha. WeeMover® plus glufosinate at 248 g ai/ha demonstrated 90 to 93% control, while the efficacy of glufosinate at 495 g ai/ha decreased from 90 to 81% during the assessment period.

### Euphorbia hirta

The effectiveness of WeeMover®, glufosinate and their combinations in controlling *Euphorbia hirta* under the mango canopy during one month of evaluation post-treatment is shown in Table 3. The results revealed that all treatments provided high levels of weed control, ranging from 90 to 93%, except for the WeeMover® treatment, which achieved 76% weed control one week after treatment (WAT).

**Table 1:** List of treatments

| S. No. | Treatment |
|---|---|
| 1 | Weedy check |
| 2 | WeeMover® |
| 3 | WeeMover® + glufosinate at 124 g ai/ha |
| 4 | WeeMover® + glufosinate at 248 g ai/ha |
| 5 | Glufosinate at 495 g ai/ha |

**Table 2:** Efficacy of herbicide treatments for control of *Ageratum conyzoides* in mature mango throughout four weeks of assessment under field conditions

| Herbicide treatment | Weed control (%) | | | |
|---|---|---|---|---|
| | Time after treatment (week) | | | |
| | 1 | 2 | 3 | 4 |
| Weedy check | 0 | 0 | 0 | 0 |
| WeeMover® | $85^{a}$ | $80^{a}$ | $75^{a}$ | $72^{a}$ |
| WeeMover® + glufosinate at 124 g ai/ha | $90^{ab}$ | $83^{ab}$ | $77^{a}$ | $72^{a}$ |
| WeeMover® + glufosinate at 248 g ai/ha | $93^{b}$ | $91^{b}$ | $90^{b}$ | $90^{b}$ |
| Glufosinate at 495 g ai/ha | $90^{ab}$ | $85^{ab}$ | $81^{ab}$ | $81^{ab}$ |

*Different subscripted letters within the same column indicate significant difference for one another after Tukey test at 5% of significant level. Weed control was rated on 0 to 100% scale; 0 denotes no scorching symptom whereas 100% denotes complete plant death

Both WeeMover® plus glufosinate treatments surpassed ($P < 0.05$) the WeeMover® treatment two WAT. All treatments maintained 92 to 100% weed control from the third week onwards.

### *Boreria latifolia*

Table 4 presents the effectiveness of WeeMover®, glufosinate and their combinations in controlling *Boreria latifolia* under the mango canopy during one month of assessment period after treatment. In the first and second WAT, WeeMover® plus glufosinate at 248 g ai/ha demonstrated superior weed control compared to glufosinate or WeeMover® alone. Notably, the weed control efficiency of WeeMover® + glufosinate at 248 g ai/ha was comparable ($P > 0.05$) to that of glufosinate at 495 g ai/ha in the third and fourth WAT. Similarly, WeeMover® + glufosinate at 248 or 124 g ai/ha achieved comparable control (83 to 92%) of *B. latifolia* within four weeks of evaluation.

## Discussion

Evans *et al.* (2011) noted that the use of 200-grain vinegar, which contains 20% acetic acid, at a rate of 700 L/ha shows promise in managing weeds among vegetable rows. The rapid weed control observed shortly after application suggests that employing vinegar within the rows could be advantageous compared to manual weeding or hoeing. Likewise, our recent study found that applying WeeMover® alone in a late post-treatment phase provided 73 to 85% control of *B. latifolia*, *A. conyzoides* and *E. hirta* one week after treatment (WAT) at 450 L/ha. This corresponds with previous research by Evans and Belinder (2009), indicating that when broadleaf weeds like buckweed (*Polygonum convolvulus* L.), common lambsquarter (*Chenopodium album* L.) and redroot pigweed (*Amaranthus retroflexus* L.) reached heights of 25 to 30 cm, the application of grain vinegar (20% acetic acid) at 636 L/ha resulted in 76% control with a 56% reduction in biomass just one day after treatment. Similarly, Chu *et al.* (2022) reported that wood vinegar, an acetic acid-based herbicide at 500 L/ha, provided 51, 68 and 83% control of common purslane (*Portulaca oleracea* L.) at 1, 3 and 5 days after treatment, respectively. Webber *et al.* (2018) also documented that 20% acetic acid applied at 187 or 935 L/ha gave 84 to 100% control of *M.verticillata* and *O. laciniata*

**Table 3:** Efficacy of herbicide treatments for control of *Euphorbia hirta* in mature mango throughout four weeks of assessment under field conditions

| Herbicide treatment | Weed control (%) | | | |
|---|---|---|---|---|
| | Time after treatment (week) | | | |
| | 1 | 2 | 3 | 4 |
| Weedy check | 0 | 0 | 0 | 0 |
| WeeMover® | $76^{a}$ | $84^{a}$ | $92^{a}$ | $92^{a}$ |
| WeeMover® + glufosinate at 124 g ai/ha | $92^{b}$ | $99^{b}$ | $100^{a}$ | $100^{a}$ |
| WeeMover® + glufosinate at 248 g ai/ha | $93^{b}$ | $98^{b}$ | $100^{a}$ | $100^{a}$ |
| Glufosinate at 495 g ai/ha | $91^{b}$ | $88^{ab}$ | $95^{a}$ | $95^{a}$ |

*Different subscripted letters within the same column indicate significant difference for one another after Tukey test at 5% of significant level. Weed control was rated on 0 to 100% scale; 0 denotes no scorching symptom whereas 100% denotes complete plant death

**Table 4:** Efficacy of herbicide treatments for control of *Borreria latifolia* in mature mango throughout four weeks of assessment under field conditions

| Herbicide treatment | Weed control (%) | | | |
|---|---|---|---|---|
| | Time after treatment (week) | | | |
| | 1 | 2 | 3 | 4 |
| Weedy check | 0 | 0 | 0 | 0 |
| WeeMover® | $73^{a}$ | $73^{a}$ | $72^{a}$ | $70^{a}$ |
| WeeMover® + glufosinate at 124 g ai/ha | $90^{b}$ | $87^{bc}$ | $83^{ab}$ | $83^{ab}$ |
| WeeMover® + glufosinate at 248 g ai/ha | $92^{b}$ | $93^{c}$ | $93^{b}$ | $92^{b}$ |
| Glufosinate at 495 g ai/ha | $80^{a}$ | $80^{ab}$ | $82^{ab}$ | $81^{ab}$ |

*Different subscripted letters within the same column indicate significant difference for one another after Tukey test at 5% of significant level. Weed control was rated on 0 to 100% scale; 0 denotes no scorching symptom whereas 100% denotes complete plant death

By 4 WAT, WeeMover® applied alone at 450 L/ha achieved between 70 to 92% control of *B. latifolia*, *A. conyzoides* and *E. hirta*. However, Abouziena *et al.* (2009) demonstrated that 30% acetic acid provided comparable efficacy in controlling broadleaf weeds like wild mustard (*Sinapis arvensis* L.) and velvetleaf (*Abutilon theophrasti* Merdik) (8 to 12 cm height) at a lower spray volume of 18.7 L/ha, suggesting that reducing the spray volume of acetic acid may be achieved by increasing its concentration to achieve satisfactory efficacy. Nevertheless, this treatment only resulted in between 20 to 60% control of certain broadleaf weeds including stranglervine (*Morrenia odorata* (Hook. & Arn.) Lindl.), blacknightshade (*Solanum nigrum* L.), sicklepod (*Senna obtusifolia* (L.) (H.S. Irwin & Barneby) and *A. retroflexus*.

The utilization of a combination of herbicide rotation and tank mixtures is crucial for managing herbicide resistance. Despite shortages of pre-mixed herbicides or tank combinations, this approach could effectively slow down the development of herbicide resistance. According to Beckie and Rebound (2009), mixing herbicides proves more effective than simply rotating them in curtailing the emergence of resistance through herbicide selection. In the present study, it is evident that the efficacy of WeeMover® in controlling *A. conzyzoides* and *B. latifolia* was further enhanced after being tank-mixed with glufosinate at half the labeled rate at 4 WAT. Furthermore, it is noteworthy that the efficacy of WeeMover® in combination with glufosinate at half the labeled rate was comparable to the full labeled rate of glufosinate applied alone, which resulted in 90 to 100% control of *B. latifolia*, *A. conyzoides* and *E. hirta* at 4 WAT despite during rainy season. This finding suggests that the glufosinate formulation contains inert ingredients that enhance the penetration of both glufosinate and acetic acid into the test weeds. Additionally, meteorological data indicated that there was no rainfall on the day the herbicide treatment was applied.

A mixture of herbicides can effectively delay resistance if the combined herbicides i) affect the same target weed, ii) have different target sites of action (Wrubel and Gressel 1994). The combination of WeeMover® and glufosinate presents a viable option for tackling problematic broadleaf weed species that have evolved resistance to herbicides since both herbicides are effective on broadleaf weeds while having different target sites of action. Herbicide-resistant *Euphobia* species and *A. conyzoides* have been identified in Brazil, Paraguay and Ecuador (Heap 2024), exhibiting resistance to various herbicide classes such as acetolactate synthase inhibitors, photosystem II inhibitors, glyphosate, or protoporphyrinogen oxidase inhibitors (Heap 2024). The WeeMover® and glufosinate mixture may serve as an alternative for controlling these herbicide-resistant weed populations.

## Conclusion

The study concluded that WeeMover® combined with glufosinate at 248 g ai/ha at 450 L/ha provided superior and consistent weed control for *Ageratum conyzoides*, *Euphorbia hirta* and *Boreria latifolia* under mango canopies. This combination outperformed WeeMover® alone and comparable to the efficacy of full rate of glufosinate at 495 g ai/ha, where the tank mixture demonstrated 90 to 100% control over a four-week period. These results suggest that the combination is a viable, efficient solution for managing broadleaved weeds in mango cultivation.

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## Author Contributions

Nurul Syafiqah Z conducted the experimental work and drafted the manuscript, under the guidance of Chuah T S. Chuah T S provided assistance in interpreting the results and preparing the manuscript. The writing process involved contributions and comments from all authors and the final version of the manuscript received approval from all of them.

## Conflicts of Interest

All authors declare no conflict of interest.

## Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

## Ethics Approval

Not applicable for this paper.

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