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Chemical Control of *Mucuna bracteata* DC. Ex Kurz Legume Cover Crop

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ABSTRACT

Mucuna bracteata *DC. ex Kurz is a fast growing leguminous ground cover planted in oil palm plantations for conserving soils, suppressing unwanted noxious weeds, recycling nutrients, and minimising rhinoceros beetles to young immature oil palm. However, its fast-growing nature and ability to regenerate very rapidly, if uncontrolled, can smother the palms. The effects of five major types of herbicides, namely glufosinate ammonium, metsulfuron methyl, glyphosate isopropylamine, paraquat dichloride, and disodium methyl arsenate, selective combination of them and the associated costs in* M. bracteata *control were evaluated to determine an economical and effective approach of managing* M. bracteata *cover in oil palm plantations. Treatments with contact herbicides were applied at four- to five-week intervals, but treatments with systemic chemicals, missed the third round of spraying because of low* Mucuna *coverage (below 70%).* M. bracteata *treated with contact herbicides showed high mortality in first week after application but the effect reduced over time and thus, had shorter control duration. Metsulfuron and other systemic chemicals caused low mortality to* Mucuna *at first but efficacy increased with time. Glufosinate ammonium (premium or original formulation) was more effective in suppressing* M. bracteata *compared to generic formulation. Selective contact disodium methyl arsenate was the least effective in legume control compared to other contact herbicides. Results showed that spraying with glyphosate+metsulfuron mixture followed by glufosinate gave longer duration of control efficacy, less labour-intensive and more economical compared with contact herbicides. This treatment is a good replacement for paraquat and the costlier repeated use of glufosinate.*

ABSTRAK

Mucuna bracteata *DC. ex Kurz adalah tanaman kekacang penutup bumi yang mempunyai kadar pertumbuhan yang tinggi dan ditanam di ladang sawit untuk memelihara tanah, mengawal pertumbuhan rumpai yang tidak diingini, mengitar semula nutrien dan mengurangkan serangan kumbang badak pada sawit yang belum matang. Namun begitu, kadar pertumbuhannya yang tinggi dan keupayaan untuk tumbuh semula dengan cepat boleh melitupi sawit jika tidak dikawal. Kesan lima jenis racun rumpai utama, iaitu glufosinat ammonium, metsulfuron metil, glifosat isoprolamin, parakuat diklorid dan disodium metil arsenat (DSMA) serta gabungan terpilih di antara racun rumpai tersebut dan kos yang berkaitan dengan kawalan* M. bracteata *telah dinilai untuk menentukan pendekatan ekonomi dan keberkesanan racun rumpai tersebut dalam mengawal pertumbuhan* M. bracteata *di ladang sawit. Rawatan dengan menggunakan racun rumpai sentuhan telah digunakan pada selang empat hingga lima minggu, tetapi rawatan dengan racun kimia sistemik, terlepas semburan pusingan ketiga kerana liputan* Mucuna *yang rendah (bawah 70%). Kadar kematian* M. bracteata *yang tinggi dicatatkan pada minggu pertama selepas dirawat dengan racun rumpai sentuhan tetapi kesannya berkurangan dari semasa ke semasa dan dengan itu, mempunyai tempoh kawalan yang lebih pendek. Metsulfuron dan bahan kimia sistemik lain menyebabkan kadar kematian* Mucuna *rendah pada mulanya tetapi keberkesanan meningkat dengan masa. Glufosinat ammonium (premium atau formulasi asal) adalah lebih berkesan dalam mengawal* M. bracteata *berbanding formulasi generik. Racun rumpai DSMA secara terpilih adalah paling kurang berkesan dalam kawalan kekacang berbanding dengan racun rumpai sentuhan yang lain. Hasil kajian menunjukkan bahawa semburan campuran glifosat+metsulfuron diikuti dengan glufosinat memberikan tempoh keberkesanan yang lebih panjang, kurang penggunaan buruh dan lebih ekonomi berbanding dengan racun rumpai sentuhan. Rawatan ini adalah pengganti yang baik untuk parakuat dan penggunaan berulang glufosinat yang kosnya lebih mahal.*

Keywords: contact, *Elaeis guineensis,* leguminous cover crops, herbicide, systemic, *Mucuna bracteata*.

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INTRODUCTION

Leguminous cover crops (LCC) have been a standard practice in tropical plantations for soil conservation and improving or maintaining soil fertility. Leguminous cover crops also suppress many common noxious or hardy weeds particularly during periods of long harvesting intervals or during fallowing periods (Akobundu, 1987; Olorunmaiye, 2010). Commonly used genera of LCC are *Mucuna, Pueraria, Calapogonium, Centrosema, Stylosanthes, Cajanus* and *Crotalaria* (Fadayomi *et al.*, 2005; Goh *et al.*, 2007).

In Malaysia, the five most common LCC adopted in oil palm and rubber plantations are *Mucuna bracteata, Pueraria javanica, Calapogonium caeruleum, Calopogonium mucunoides,* and *Centrosema pubescens* (Goh *et al.*, 2007; Kobayashi *et al.*, 2003). The former was recently introduced to plantations in both Malaysia and Indonesia due to its desirable characteristics of fastest growing, perennial, persistent, shade tolerant, and competitive against common noxious weeds (Chiu, 2004; 2007; Goh *et al.*, 2007; Mathews, 1998). Furthermore, in oil palm plantations, its ability to generate up to three to four times more biomass compared to other LCC (Goh *et al.*, 2007) also contributed to its popularity and wide acceptance. Apart from the beneficial effects of LCC on tropical oil crops, leguminous ground cover crops were reported to also improve the soil structure and aeration (Chan *et al.*, 1979), minimise rhinoceros beetle population in oil palm replanting areas (Wood, 1968), as well as reduce weed-palm competition through smothering the unwanted weeds, which gave 20% increase in oil palm yield (Yeow *et al.*, 1982).

M. bracteata can proliferate fast and vigorously due to its aggressive generating vines that can grow approximately 0.75 – 1 m per week with thick stems and pseudo tap roots penetrating to a depth of 2 – 3 m (Chiu, 2007; Mathews, 1998). When left uncontrolled, *M. bracteata* can thrive well on the intended weed-free ground area under newly planted oil palm seedlings or immature oil palms, climb, entangle, and smother them (Chung and Chang, 1990), resulting in poor or stunted palm growth or possibly eventual death. Furthermore, with the ability to produce huge amount of leaves and biomass, *M. bracteata* can form a thick layer of litters up to a thickness of 39 to 90 cm (Mathews, 1998). Uncontrolled, overly thick *M. bracteata* can hinder accessibility to estate management particularly in pruning operation, harvesting, collection of loose fruits, crop evacuation, as well as fertiliser application. When *M. bracteata* is well established, keeping it under control is much more difficult and costly because of its fast capability to regenerate. More frequent herbicide control rounds are required. Hence, an effective, less labour-intensive and longer-lasting control is needed to overcome the disadvantages of *M. bracteata* while preserving its advantages as a leguminous cover crop. The objectives of this experiment were to evaluate five major types of herbicides, namely glufosinate ammonium, metsulfuron methyl, glyphosate isopropylamine, paraquat dichloride, and disodium methyl arsenate (DSMA), selective combinations of them and their associated costs in *M. bracteata* control, and develop a cost-effective method to manage *M. bracteata.*

MATERIALS AND METHODS

Site Descriptions and Field Experimental Set-up

Field experiments were conducted in Balau Oil Palm Estate, Semenyih, Selangor, Malaysia with coordinate of 2.92° N and 101.87° E and started in May 2010 on a coarse sandy soil (Rengam soil series – *Typic Kandiudult*). Monthly rainfall records during the trial period from May to October were 335, 210, 116, 246, 183, and 228 mm, respectively, with number of rain day records ranging from 10 to 15 days per month. The main ground vegetation for all the experimental plots was *M. bracteata* (approximately 98% to 100% for the whole block). The experiment was arranged in a randomised complete block design (RCBD) and plot size was 2 x 20 m^2 each with three replications for each treatment.

Herbicide Treatments

Chemical herbicides were sprayed and applied to the designated plots as per the manufacturer's recommendation at a rate equivalent to 450 litres of water per hectare based on spray-to-wet technique at four different time points – weeks 0, 4, 9, and 14. The list of treatments for this experiment are outlined and described in *Table 1*. Frequency of herbicide application varied amongst treatments depending on the regeneration of *M. bracteata.* Re-application of herbicides in all the treated plots on four separate time points (week 0, 4, 9 and 14) (estate practice) was based on the threshold of 50% *M. bracteata* coverage as the minimum criteria. This was to prevent *M. bracteata* from smothering the palms. Re-application of herbicides in the treatment plots of 4, 5, 6, 7 and 9 was carried out on week 9 as the plots had more than 50% *M. bracteata* and other weeds coverage (*Table 1*). Weekly assessment was carried out to determine the rate of *M. bracteata* regeneration, the coverage of *Mucuna* covers and emergence of other weeds within the treated plots. *Mucuna bracteata* mortality (%) was determined by the following formula:

M. bracteata mortality = [(MBC – MBT) / MBC] x 100%, where MBC is the *M. bracteata* coverage (%) in the control plot and MBT is the *M. bracteata*

TABLE 1. CHEMICAL HERBICIDES AND COMBINATIONS USED IN THIS EXPERIMENT FOR FOUR SEPARATE TIME POINTS (week 0, 4, 9 and 14)

	Active ingredients** and rate‡			
Treatment	**Week 0**	**Week 4**	**Week 9**	**Week 14**
T1*	Control	Control	Control	Control
T2	GA	GA	GA	GA
T3	GA (Generic)	GA (Generic)	GA (Generic)	GA (Generic)
T4	MM	GA	‡‡	GA
T5	MM	GA	‡‡	MM
T6	GI+MM	GA	‡‡	GA
T7	GI+MM	GA	‡‡	GI+MM
T8	PD	PD	PD	PD
T9	PD+MM	PD+MM	‡‡	PD+MM
T10	DSMA	DSMA	DSMA	DSMA

Note: * Treatment 1 (control) was without any chemical herbicide treatment.
** Abbreviations for all the active ingredients used: GA (glufosinate ammonium 13.5%); MM (metsulfuron methyl 20%); GI (glyphosate isopropylamine 41%); PD (paraquat dichloride 44%); and DSMA (disodium methyl arsenate 36%).
‡ Standardised treatment rate for all the chemical herbicides used based on 450 litres ha^{-1} of water: GA (3.3 litres ha^{-1}); MM (75 g ha^{-1}); GI (1.5 litres ha^{-1}); PD (5.4 litres ha^{-1}); and DSMA (4.0 litres ha^{-1}).
‡‡ It was below the threshold level of 50% legume coverage. Therefore, no treatment was conducted at this time point.

coverage (%) in the plot subjected to treatment. Mortality was defined as dry or desiccated to dead *M. bracteata* leaves.

The herbicides tested were two types of glufosinate ammonium 13.5% (premium/original formulation and one generic product/formulation); metsulfuron methyl 20%; glyphosate isopropylamine 41%; paraquat dichloride 44%; and DSMA 36%. Blanket spraying for all the demarcated plots was carried out manually using an INTER knapsack sprayer (16 litres) with fan jet nozzle.

Statistical Analysis

M. bracteata mortality for each of the respective week of census was calculated based on the data obtained from weekly census (weeks 1 to 18) and analysed using SPSS (4th version) statistical software. All data were checked for normal distribution with Anderson-Darling test and transformed when necessary using logit transformation. Numbers presented in both figures and tables are untransformed means and standard errors. Differences in means for the percent of *M. bracteata* mortality for the plots treated with contact herbicides and non-treated control, namely premium/original formulation of glufosinate ammonium (T2), generic glufosinate ammonium (T3), paraquat dichloride (T8), DSMA (T10), and control (T1) on weeks 1, 5, 10, and 15 (a week after each round of treatment); the mortality of *M. bracteata* in each individual census week; percent of ground coverage for other weeds in all the treatments at 12 different census time points (from weeks 7 to 18); and percent of *M. bracteata* coverage for all the plots treated with systemic herbicides, namely treatments – 4, 5, 6, 7 and 9 together with control at weeks 1, 3, 5, 7, 9 and 10 were determined using analysis of variance (ANOVA) and Fisher's least significant different (LSD) test at $P = 0.05$ (SPSS, 1990).

RESULTS

Effect of Contact Herbicides on Legume Mortality

Weed mortality or weed killed was proposed as one of the most commonly used and relatively effective indicator for evaluating the weed control efficacy of chemical herbicides. All the contact chemical herbicides tested in this experiment showed significantly higher *M. bracteata* mortality compared to untreated control one week after respective round of treatment (*Figure 1a*). Premium of glufosinate ammonium and paraquat dichloride consistently gave above 80% *M. bracteata* mortality one week after spraying. Efficacy of *M. bracteata* control by paraquat dichloride was slightly lower compared to premium glufosinate ammonium, especially at two weeks after treatment. Premium glufosinate ammonium constantly gave better *M. bracteata* control compared to the tested generic glufosinate ammonium formulation (*Figure 1a*). DSMA was less effective for controlling *M. bracteata* compared to glufosinate ammonium and paraquat dichloride herbicides in this experiment. Based on the benchmarks proposed by Burrill *et al.* (1976), the minimum acceptable levels of weed control efficiency is approximately 70% and above mortality, with 90% weed mortality being excellent. Treatments with premium glufosinate ammonium and paraquat dichloride were considered to be having excellent efficacy in suppressing *M. bracteata* with >90% mortality one week after spraying (*Figure 1a*). In addition, premium glufosinate ammonium was the only contact herbicide tested with the ability to maintain the minimum acceptable level of *Mucuna* control efficiency of >70% mortality for between two to three weeks after application (*Figure 1a*). *M. bracteata* mortality for generic glufosinate ammonium at a week after treatment was between 64% to 82%. DSMA had the lowest efficacy, giving <60% *M. bracteata* mortality (*Figure 1a*). Therefore, the efficacy of weed control for the four tested contact herbicides based on percent of *M. bracteata* mortality in descending order was: premium glufosinate ammonium > paraquat dichloride > generic glufosinate ammonium > DSMA.

Effect of Systemic Herbicides on Legume Mortality

Mortality of *M. bracteata* in the treatment plots with metsulfuron methyl alone was significantly lower compared to the treatments with glyphosate isopropylamine + metsulfuron methyl mixture and paraquat dichloride + metsulfuron methyl mixture in one to four weeks after the first round of spraying (*Figure 1b, Table 2*). Furthermore, percentages of mortality for *M. bracteata* in the treatment plots treated with contact herbicides, namely glufosinate ammonium (premium and generic) and paraquat dichloride, was significantly higher for the first three weeks after spraying compared to those treatment with metsulfuron methyl only (*Table 2*). Spraying metsulfuron methyl followed by premium glufosinate ammonium (T4 and T5) kept *M. bracteata* cover under 50% for around six to nine weeks. In addition, spraying glyphosate isopropylamine + metsulfuron methyl mixture followed by premium glufosinate ammonium (T6 and T7) kept the coverage of *M. bracteata* under 50% for around nine to 10 weeks. Repeating the spraying of paraquat dichloride + metsulfuron methyl (T9) kept the legume coverage below 50% only up to six weeks (*Tables 2* and *3*). However, this treatment (T9) was able to control the growth of other weeds; in particular *Mikania, Cleome,* and *Eupatorium* species (data not shown) to below 20% compared to treatments T4 to T7, which had growth of other weeds up to as high as 45% prior to the fourth round of spraying on week 14 (*Table 4*). Hence, the regeneration of other weeds in the T4 to T7 treatments was relatively faster compared to T9 (*Table 4*). Twice continuous spraying of paraquat dichloride + metsulfuron methyl mixture (T9) was superior compared to spraying metsulfuron methyl followed by premium glufosinate ammonium (T4 and T5) or glyphosate isopropylamine + metsulfuron methyl mixture followed by premium glufosinate ammonium (T6 and T7) (*Figure 1b* and *Table 4*).

Cost Comparison

Table 5 illustrates the total weeding cost per hectare of oil palm inclusive of both chemical herbicide and labour cost. Treatments with a mixture of two different chemical and alternating with similar or different herbicides (T4 to T7 and T9) cost less compared to treatments with premium or generic glufosinate ammonium (T2 and T3) and DSMA (T10) (*Table 5*). Hence, mixture of more than one herbicides and alternating the herbicides sequentially would lower the weeding cost per hectare and was more effective in controlling *M. bracteata* (*Tables 2, 3* and *5*).

DISCUSSION

Incorporation of herbaceous leguminous *M. bracteata* and other commonly used legume cover crops into conventional agricultural system, especially in oil palm plantations, was mainly because of their beneficial effects, such as soil moisture conservation, soil erosion and runoff controls, minimise proliferation of noxious weeds, recycling of nutrients and improve the soil organic matter content (Goh *et al.*, 2007). Despite the benefits, keeping the legume under control is crucial yet difficult and costly.

The result from this field experiment indicates that the *M. bracteata* mortality in all the plots treated with contact herbicides were significantly higher compared to untreated control (*Figure 1a*). Differences in the killing action of *Mucuna* between contact and systemic herbicides were observed in this experiment (*Figure 1*). Contact herbicides gave high mortality for first week but reduced over time (*Figure 1a*), while metsulfuron methyl and other systemic chemicals (treatments: T4 to T7 and T9) gave low mortality at first but increase over time (*Figure 1b*). Paraquat dichloride plus metsulfuron methyl (T9) gave high mortality in the first few weeks. However, if the mixture of paraquat dichloride + metsulfuron (T9) was used instead of glu-

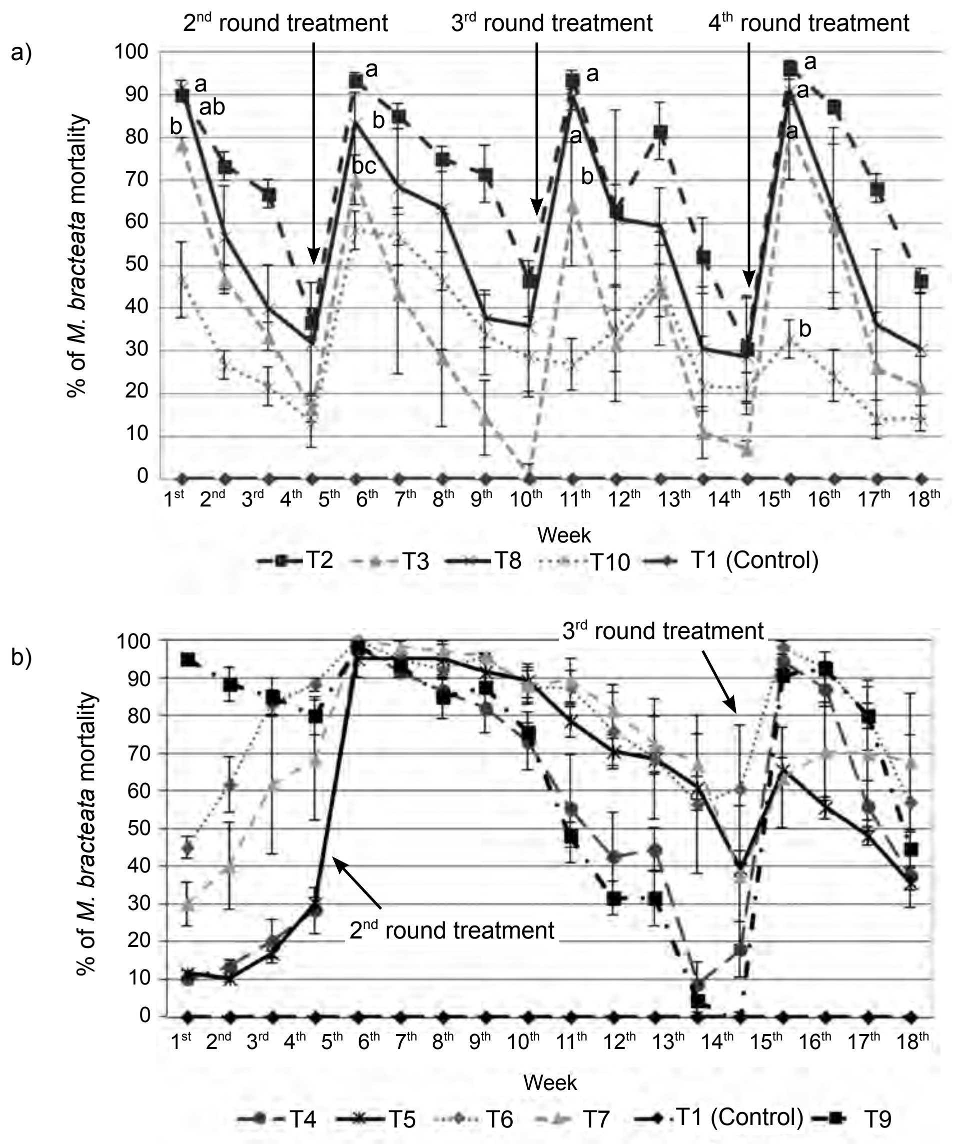

Figure 1. Percent of Mucuna bracteata *mortality at 18 different time points with four rounds of contact (a) and three rounds of systemic (b) herbicide treatments/sprayings. Means within the same time point for the treatments with contact herbicides (a), followed by the same letter, are not significantly different at P < 0.05 with Fisher's LSD test for weeks 1, 5, 10, and 15 (a week after each round of treatment). Error bars are the standard errors. Abbreviations on all the treatments shown here were outlined in* Table 1.

fosinate ammonium in the subsequent spray, the duration of *Mucuna* control was shorter with lower control efficacy compared to other treatments (T4 to T7) (*Figure 1b*). Lower *Mucuna* control efficiency was noted if metsulfuron methyl was followed by premium glufosinate ammonium (T4 and T5) compared to a mixture of glyphosate plus metsulfuron methyl followed by premium glufosinate ammonium (T6 and T7), indicating that glyphosate has higher phytotoxic effect on *M. bracteata* (*Figure 1b*).

Premium glufosinate ammonium gave better control efficiency compared to the tested generic formulation. This could be partially due to different methodology in preparing the formulation and type of adjuvant or surfactant added. In addition, premium glufosinate ammonium was observed to pose higher percentage of weed kill or mortality compared to other contact herbicides; therefore, it was able to maintain the legume coverage under 50% for approximately three to four weeks after spraying (*Figure 1a*). This is in accordance to the study conducted by Mohamad *et al.* (2010) stating that there is a positive correlation between percent of weed killed and extension of the duration in control efficacy. Furthermore, premium glufosinate ammonium was found to be more effective in controlling *Mucuna* compared to paraquat dichloride (*Figure 1a*). This result agrees with a few previous studies (Mohamad *et al.*, 2010; Wibawa *et al.*, 2009) where lower rates of glufosinate ammonium were required to suppress weed growth compared to paraquat dichloride (Wibawa *et al.*, 2007). Moreover, paraquat dichloride, a non-selective contact

TABLE 2. MORTALITY OF LEGUMINOUS *Mucuna bracteata* COVER CROPS (in %) FOR 10 SEPARATE TREATMENTS (control, contact and systemic herbicides) AT 18 DIFFERENT CENSUS TIME POINTS

Treatment		Week																	
		1	2	3	4*	5	6	7	8	9**	10	11	12	13	14‡	15	16	17	18
Control	1	0g	0g	0e	0c	0d	0c	0e	0e	0d	0g	0d	0d	0d	0e	0d	0d	0d	0d
	2	90b	73b	67abc	37b	93a	85a	75bc	71b	46b	94a	63abc	81a	52ab	30abcd	96a	87ab	68ab	46abc
	3	78c	47cd	33d	17b	70bc	43b	28d	14d	1c	64cde	31c	44bc	11bc	7d	82ab	59bc	26abc	21bc
	8	92ab	57bc	40cd	32b	83ab	68ab	63bc	38c	36b	89ab	61abc	59abc	30abc	29abcd	91a	63ab	36bc	30bc
Contact	10	47d	27de	22d	13b	58c	57b	47cd	34c	29b	27f	35c	46bc	22abc	21abcd	33c	24c	14c	14c
	4∞	10f	13ef	20d	28b	98a	92a	87ab	82ab	73a	55def	43bc	44bc	9bc	18bcd	95a	87ab	56ab	38abc
	5∞	12f	10f	17d	30b	95a	95a	95a	92a	89a	79bcd	70abc	69ab	61ab	39abc	65bc	56bc	48abc	36bc
	6∞	45d	62bc	83ab	88a	100a	95a	92a	96a	88a	88abc	76ab	69ab	57ab	61a	98a	93ab	80a	57ab
	7∞	30e	40cd	62bc	68a	100a	98a	97a	96a	88a	89abcd	81a	72ab	67a	38ab	64bc	70ab	70a	68a
Systemic	9∞	95a	88a	85a	80a	98a	93a	85ab	88ab	76a	48ef	31c	31c	4c	0cd	91a	93a	80a	45abc
S.E.	-	5.1	9.7	11.1	12.2	4.9	9.9	10.5	5.9	5.9	11.7	10.0	13.5	15.6	14.7	9.4	16.3	15.5	15.4

Note: *Second treatment or spraying on week 4. **Third treatment or spraying on week 9, except treatment plots – 4 to 7 and 9 (∞with *M. bracteata* coverage below 50%). ‡ Fourth treatment or spraying on week 14. Means within the same column, followed by the same letter, are not significantly different at $P < 0.05$ with Fisher's LSD test. S.E. is defined as standard error.

TABLE 3. PERCENT OF *Mucuna bracteata* COVERAGE (in %) AND DURATION OF CONTROL (months) FOR PLOTS TREATED WITH SYSTEMIC HERBICIDES AND CONTROL BEFORE AND AFTER THE SECOND ROUND OF SPRAYING ON WEEK 4 OF THE EXPERIMENT

Treatment	Week(s) before/after second round of spraying														Duration of control (months)
	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10*	
1	100a	100a	100a	100a	100a	100a	100a	93a	93a	93a	90a	90a	77a	93a	-
4	90ab	87a	80a	72b	2c	8b	13bc	17b	25b	42bc	52b	50b	70a	77a	Up to 6 weeks after spraying at 42%
5	88b	90a	83a	70b	5b	5b	5cd	8bc	10c	20cd	27c	28c	30b	57ab	Up to 9 weeks after spraying at 30%
6	55d	38c	17b	12c	0c	5b	8bcd	4c	12bc	12d	22c	28c	33b	37b	Up to 10 weeks after spraying at 37%
7	70c	60b	38b	32c	0c	2b	3d	4c	11c	10d	17c	25c	25b	58ab	Up to 9 weeks after spraying at 25%
9	5e	12d	15b	20c	2c	7b	15b	12b	23bc	48b	62b	62b	73a	95a	Up to 6 weeks after spraying at 48%
S.E.	1.9	4.2	6.0	6.1	0.7	0.8	2.1	2.3	3.2	5.1	5.6	6.5	8.1	8.8	

Note: *Fourth round of treatment or spraying being conducted. Means within the same column, followed by the same letter, are not significantly different at $P < 0.05$ with Fisher's LSD test. S.E. is defined as standard error.

TABLE 4. PERCENT OF GROUND COVERAGE FOR OTHER WEEDS (in %) FOR 10 SEPARATE TREATMENTS AT 12 DIFFERENT CENSUS TIME POINTS

Treatment	Week											
	7	8	9**	10	11	12	13	14‡	15	16	17	18
1	0b	7b	7ab	7bc	10bc	10c	23ab	7bc	8bcd	10bc	17abc	7b
2	3b	7b	7ab	1d	8bc	13abc	13b	20abc	2cd	7bc	17abc	8b
3	0b	2b	2c	0d	8bc	12bc	13b	10bc	3bcd	7bc	13abc	10b
8	5b	8b	18ab	0d	7c	20bc	17ab	18abc	5d	12bc	10c	12b
10	22a	17a	20a	22ab	32ab	42a	33ab	27abc	30abc	27ab	25abc	17ab
4$^{\infty}$	0b	2b	2c	2cd	12bc	25abc	12b	15bc	3bcd	10bc	17abc	17b
5$^{\infty}$	5b	4b	12ab	23a	40a	40a	43a	35ab	60a	42a	47a	27ab
6$^{\infty}$	1b	4b	7ab	10c	22ab	38ab	30ab	45a	25abc	35ab	43ab	28a
7$^{\infty}$	1b	3b	4bc	5c	17bc	33abc	30ab	30abc	40ab	25ab	28abc	17b
9$^{\infty}$	2b	3b	2c	5cd	13bc	17c	12b	5c	3d	12bc	15bc	12b
S.E.	4.8	4.1	7.4	4.2	7.1	10.1	13.0	12.7	11.9	12.9	15.2	10.3

Note: ** Third treatment or spraying on week 9, except treatment plots – 4 to 7 and 9 ($^{\infty}$with *M. bracteata* coverage below 50%).

‡ Fourth treatment or spraying on week 14. Means within the same column, followed by the same letter, are not significantly different at $P < 0.05$ with Fisher's LSD test.

herbicide, has been reported to be less effective towards perennial weeds as opposed to small newly established weeds or annual grasses (Collins, 1991). Among the four chemical contact herbicides tested, DSMA showed the least efficacy (*Figure 1a*). Rumburg *et al.* (1960) reported that DSMA has the ability of selectively control crabgrass in turf areas and some other grasses but not the broadleaves. Therefore, this might be part of the factor that contributed to low *Mucuna* control efficacy.

Since the Malaysian government has imposed stringent rules to the use of paraquat dichloride (Wibawa *et al.*, 2007), glufosinate ammonium and glyphosate were proposed to be used in the plantations as an alternative. Furthermore, glyphosate and glufosinate ammonium were considered to have less negative impacts to the environment (Malone *et al.*, 2004). In addition, combination of metsulfuron methyl with other chemical herbicides, especially glyphosate isopropylamine or glufosinate ammonium, or alternating sequentially with a mixture of herbicide amended with metsulfuron methyl, were proposed to be another superior alternative to paraquat dichloride (Chung and Chang, 1990; Mathews and Saw, 2007). Results obtained from current experiment illustrate that those treatments supplemented with metsulfuron methyl were superior and provided longer duration of *Mucuna* control compared with contact chemical herbicides (*Tables 2* and *3*). Metsulfuron methyl was reported to be relatively persistent in the fields and the rate of degradation for this chemical decreased as the soil depth increased (Walker *et al.*, 1989). Chemical with the systemic characteristics, in particular high efficiency in translocating the chemical from foliar to other parts of the plant in a distant site allowed systemic herbicides to give better control of perennial or well-established weeds compared to contact chemical that is more superficial in damaging the weeds (Kremer and Mean, 2009; Pittenger, 2002). In this experiment, one initial spray using glyphosate isopropylamine mixed with metsulfuron methyl followed by glufosinate ammonium maintained *Mucuna* coverage under 50% up to 9 to 10 weeks (*Table 3*). A study by Ahmad Faiz (2006) illustrated that glyphosate isopropylamine amended with metsulfuron methyl gave longer duration in terms of weed control efficacy compared with glufosinate ammonium and slashing. In a separate study, Pline *et al.* (2000) described that glyphosate showed higher efficacy in terms of suppressing the regeneration of perennial noxious weeds tested compared to glufosinate. Most of the oil palm and rubber plantations have voluntarily opted to discontinue the use of paraquat dichloride or reduce its usage, metsulfuron methyl alternate with glufosinate ammonium (T4 and T5) and glyphosate isopropylamine + metsulfuron methyl mixture alternate with glufosinate ammonium (T6 and T7) which have lower cost per hectare compared to contact herbicides (*Table 5*) could be the alternatives. However, repeated applications with glyphosate isopropylamine + metsulfuron methyl mixture or glyphosate alone can cause severe dieback of *M. bracteata* and eventually killing it.

TABLE 5. TOTAL COST REQUIRED FOR 1 ha OF OIL PALM BLOCK WITH BOTH CHEMICAL HERBICIDES AND LABOUR COST INCLUDED

Treatment	Chemical cost* (RM)	Spraying rounds	Labour cost** (RM)	Total cost (RM)
1	-	-	-	-
2	567.60	4	80	647.60
3	541.20	4	80	621.20
4	292.80	3	60	352.80
5	159.90	3	60	219.90
6	319.05	3	60	379.05
7	212.40	3	60	272.40
8	189.00	4	80	269.00
9	168.75	3	60	228.75
10	576.00	4	80	656.00

Note: * Calculated for all the chemical herbicides used per hectare and based on the retails price for year 2011.
** Assuming labour cost per man day for each hectare is approximately RM 20 with an assumption that on average a worker can do palm circle spraying for 2 ha a day.

Therefore, glyphosate or glyphosate + metsulfuron methyl mixture should be alternated with contact herbicides, such as glufosinate ammonium to prevent extensive diebacks of *M. bracteata.*

CONCLUSION

Premium glufosinate ammonium was more effective in suppressing *M. bracteata* compared to one generic formulation tested. Thus, before using any generic glufosinate ammonium, they should be field tested for their efficacy and cost effectiveness. Selective DMSA was the least efficient in legume control compared to other contact herbicides tested. Our results showed that spraying glyphosate isopropylamine + metsulfuron methyl mixture followed by glufosinate ammonium can give longer duration of control efficacy at a lower cost per hectare compared to contact herbicides which is a good replacement for paraquat and costlier repeated applications of glufosinate ammonium for two years old palms or older. However, extreme care should be accorded to prevent phytoxicity of glyphosate and metsulfuron methyl towards oil palms.

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