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Control of *Mucuna bracteata* DC. Ex. Kurz Legume Covers with Herbicides in Oil Palm Plantation: Spraying Volume and Frequency

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ABSTRACT

Leguminous Mucuna bracteata *DC. ex. Kurz is one of the most commonly planted ground covers in oil palm plantations. However, under uncontrolled conditions, the covers can smother and entangle the palms, especially in young immature plantings. Efficacy of five major types of herbicides - paraquat dichloride (PD), glyphosate isopropylamine (GI), metsulfuron methyl (MM), glufosinate ammonium (GA), and disodium methyl arsenate (DSMA), as well as ammonium chloride with two separate spraying volumes and two different spraying frequencies, in controlling* M. bracteata *were studied. Variable spraying volume or spray-to-wet method caused higher* M. bracteata *mortality compared to fixed volume spraying. The PD, GI+MM mixture and GA were observed to give better control of* M. bracteata *compared to other treatments. Multifactorial ANOVA illustrated that herbicide, volume and frequency were showing significant post-spraying influence on both percent of casualty and alive* M. bracteata *after most of the spraying rounds. Interactions between herbicide x volume, herbicide x frequency, and herbicide x volume x frequency were spotted in a few post-spraying census. However, there was no interaction found in volume x frequency. Results showed that spraying with GI+MM mixture could be one of the promising herbicide combinations with spray-till-wet technique and variable spraying rounds (re-application as* M. bracteata *covered > 70%) was the most efficient treatment and with reduced effect on* M. bracteata *regeneration.*

ABSTRAK

Pokok kekacang, Mucuna bracteata *DC. ex. Kurz merupakan tanaman penutup bumi yang biasa ditanam di ladang sawit. Walau bagaimanapun, dalam keadaan yang tidak terkawal, tanaman penutup bumi ini boleh melitupi dan menjerut sawit, terutamanya sawit yang belum matang. Kajian ini dijalankan untuk mengetahui keberkesanan lima jenis racun rumpai utama dalam mengawal* M. bracteata *- parakuat diklorid (PD), glifosat isoproplamin (GI), metsulfuron metil (MM), glufosinat ammonium (GA), dan disodium metil arsenat (DSMA), serta ammonium klorida dengan dua jumlah semburan berasingan dan dua frekuensi semburan yang berbeza. Jumlah semburan yang berubah atau kaedah semburan hingga basah menyebabkan kadar kematian* M. bracteata *lebih tinggi berbanding jumlah semburan tetap. PD, campuran GI + MM dan GA didapati dapat memberi kawalan yang lebih baik terhadap* M. bracteata *berbanding rawatan lain. Multifaktorial ANOVA membuktikan bahawa jenis racun, jumlah dan kekerapan semburan memberi pengaruh yang signifikan ke atas peratus* M. bracteata *yang hidup dan mati selepas pusingan awal semburan. Interaksi antara racun rumpai x jumlah racun, racun rumpai x frekuensi semburan, dan racun rumpai x jumlah x kekerapan telah dikesan dalam beberapa kajian selepas semburan awal. Walau bagaimanapun, tidak terdapat interaksi di antara jumlah racun rumpai x frekuensi semburan. Hasil kajian menunjukkan bahawa semburan dengan GI + MM boleh menjadi salah satu daripada gabungan racun rumpai yang berkesan dengan teknik semburan-hingga-basah dan pelbagai pusingan semburan (aplikasi semula bagi* M. bracteata *menutupi > 70%) adalah rawatan yang paling berkesan dan mampu mengurangkan pertumbuhan semula* M. bracteata.

Keywords: chemical, *Elaeis guineensis,* immature planting, legume ground cover.

INTRODUCTION

Leguminous ground covers and other non-legume covers have been integrated into the temperate and tropical farming systems with highly weathered soils and poor soil fertility in the effort to improve sustainability. Leguminous cover crops (LCC) can

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conserve the soil they grow on, improving soil fertility through nutrient recycling, increase soil carbon contents and nitrogen-fixation, conserve quality of ground water, suppressing noxious weeds, and help to reduce pests (Blanchart *et al.*, 2006; Ingels *et al.*, 1994; Reddy, 2001). Integration of legume cover crops into agricultural systems has long been practiced in cereal and oil crops (Olorunmaiye, 2010; Sarrantonio and Gallandt, 2003; White and Worsham, 1990) and vegetable farming (Masiunas, 1998). Masiunas (1998) highlighted that integration of legumes, small grains or grass cover crops as the living mulches can alter the microclimate of the agricultural lands through lowering down the surface temperatures. Fast-growing and aggressive nature of perennial legumes, besides having allelopathic properties, that allow them to thrive easily and suppress relatively big number of hardy weeds in most of the agricultural lands (Akobundu, 1987; Masiunas, 1998). In Malaysia and Indonesia, five common LCC adopted and practiced by major oil palm and rubber plantations are *Mucuna bracteata, Pueraria javanica, Calapogonium caeruleum, Calopogonium mucunoides, Centrosema pubescens*, or the mixture of these legumes (Goh *et al.*, 2007). Among the five LCC, *M. bracteata* is the most preferred legume cover crops in both Malaysia and Indonesia due to a few of the most desirable characteristics – fast-growing or aggressive, perennial, persistence, huge biomass, able to compete with other noxious weeds, and shade tolerant (Chiu, 2004; 2007; Goh *et al.*, 2007; Mathews, 1998).

M. bracteata was reported to have the ability to grow vigorously by producing vegetative vines that can grow up to approximately a metre per week, having thick stems and pseudo tap roots that can proliferate as well as penetrate to a depth of 2 – 3 m (Chiu, 2007; Mathews, 1998). When left uncontrolled, it can climb over and entangle the newly planted seedlings or immature oil palms (Chiu, 2007; Chung and Chang, 1990; Tarawali *et al.*, 1999). This will eventually lead to poor palm growth and may even cause palm death. In addition, the most desired characteristic of this legume that attracts much attention is its ability to produce three to four times more biomass than conventional legumes (Goh et al., 2007). *M. bracteata* can produce large amount of above-ground biomass and form a thick layer of leaves up to a height of 39 to 90 cm (Mathews, 1998). Palm circles overpopulated with high density of *M. bracteata* impede accessibility and can hinder oil palm management routines such as pruning of fronds, harvesting of ripe bunches, collection of loose fruits, crop evacuation, and fertiliser application. During the high rainfall periods, *M. bracteata* was recorded to achieve even faster growth (Lee *et al.*, 2005), making it even more difficult to control. The aims of our experiment were to evaluate five major types of active ingredients with their respective mode of actions (Böger *et al.*, 2002; Fedtke, 2012; Ross and Childs, 1996), in particular paraquat dichloride (contact, non-selective, and causing disruption in plant cell membrane), glyphosate isopropylamine (systemic, non-selective, and inhibiting plant enzyme involved in aromatic amino acids synthesis), metsulfuron methyl (systemic, non-selective, acting as amino acid inhibitors, and inhibiting root and shoot cell division), glufosinate ammonium (contact, non-selective, post-emergence, and inhibiting glutamine synthetase enzyme), and disodium methyl arsenate (DSMA) (contact, selective, and interfering with plant ATP production and cell division), as well as ammonium chloride salt. Furthermore, the optimum combination of the herbicides or chemicals and cost associated with the respective treatments for controlling *M. bracteata* were studied as well. Moreover, all the chemical herbicides were also combined with two separate spraying volumes and two different spraying frequencies.

MATERIALS AND METHODS

Site Descriptions and Field Experimental Set-up

Field experiments were carried out at the Advanced Agriecological Research Sdn Bhd (AARSB) Experimental Substation at the Balau Oil Palm Estate, Semenyih, Malaysia with coordinate of 2.92° N and 101.87° E and started in May to September 2009 on a coarse sandy soil (Rengam soil series – *Typic Kandiudult*) (Paramananthan, 2000) field. Monthly rainfall for year 2009 at the experiment site during the trial period were 54 mm in May, 80 mm in June, 94 mm in July, 179 mm in August, and 220 mm in September with number of rain day records ranging from 2 to 11 days per month. Furthermore, there were three continuous low rainfall months (< 100 mm per month), which occurred from May to July. The major ground vegetation for all the experimental plots was *M. bracteata* (approximately 98% to 100% coverage). The experiment was designed and arranged in a randomised complete block design (RCBD) and the plot size was 1 x 1 m^2 with three replications for each treatment. The list of treatments is outlined in *Table 1* with six type of chemicals, each chemical was applied at two different spray volumes (fixed 90 ml per plot or spraying the entire to wet) and two separate spraying frequencies (fixed monthly or when *Mucuna* cover reached >70%) and all combinations were with three replications, giving a total of 72 plots.

TABLE 1. HERBICIDES AND CHEMICALS TESTED – SPRAYING VOLUME AND FREQUENCY

Treatment	Rate per hectare	Spraying volume	Spraying frequency
Untreated control (C)	-	-	-
Paraquat dichloride (PD)	5.4 litres ha^{-1}	1) Fixed volume (90 ml spraying)	1) Fixed interval (monthly)
Glyphosate isopropylamine + metsulfuron methyl (GI+MM)	1.5 litres ha^{-1}+ 75 g ha^{-1}	-	-
Glufosinate ammonium (GA)	3.3 litres ha^{-1}	2) Variable volume (spray to wet)	2) Variable interval** (> 70% live *Mucuna bracteata*)
Metsulfuron methyl (MM)	75 g ha^{-1}	-	-
Ammonium chloride (AC)	135 kg ha^{-1}	-	-
Glufosinate ammonium + DSMA (GA+DSMA)	1.65 litres ha^{-1}+ 2 litres ha^{-1}*	-	-

Note: * Half of manufacturer's recommended rate for both GA and DSMA was used.
** Re-application of the herbicides was determined based on the live *Mucuna* coverage threshold of more than 70%.

Herbicide Treatments

Chemical herbicides were sprayed and applied to the designated plots as per manufacturer's recommendation at a rate equivalent to 450 litres of water per hectare (commonly used volume for blanket spraying in the plantation) and half of the recommended rates for glufosinate ammonium mixed with DSMA (half rate) (*Table 1*). All the chemicals selected for this experiment were applied based on the fixed 90 ml spray volume or spray-to-wet (variable volume) technique at two different spraying frequencies, namely fixed month interval or when the *Mucuna* cover reached >70% (variable) (*Table 1*). Weekly census was carried out to determine the percentage of live and affected/ dead *M. bracteata* within the treated plots.

The chemical herbicide formulation used were two types of paraquat dichloride 44%; glyphosate isopropylamine 41%; metsulfuron methyl 20%; glufosinate-ammonium 13.5% (one premium or original formulation and one generic product); and disodium methyl arsenate 36%. Ammonium chloride 25% N was purchased from Behn Meyer, Malaysia. Spraying for all the demarcated plots was performed manually using an INTER knapsack sprayer (16 litres) with flat jet nozzle.

Statistical Analysis

Live and dead *M. bracteata* after treatments were scored in weekly census (week 1 to 17) and analysed using Minitab (15^{th} version) statistical software (Minitab Ltd, Coventry, UK). 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 percentage of *M. bracteata* casualty for all the treated and control plots on weeks 1, 2, 5, 6, 9, 10, 13, and 14 (one and two weeks after each round of spraying) (usually the legume covers in most of the treatments were more than 70% starting from week 3 onward) were determined using analysis of variance (ANOVA) and Fisher's least significant difference (LSD) test at $P = 0.05$ significance level (Minitab 15) to evaluate the efficacy of the tested chemicals. In addition, differences in means for the percent of live and killed *M. bracteata* on the census weeks 1, 5, 9 and 14 (one week after respective round of spraying) were analysed using ANOVA-GLM (general linear model) method (Minitab 15); to assess the interactions between treatments. Means were then separated using Tukey's simultaneous test at $P = 0.05$.

RESULTS AND DISCUSSION

Effect of Spray Volume

Spray volume, dosage and concentration of chemical used to control the weeds may affect the efficacies of herbicides (McKinlay *et al.*, 1974; Ramsey *et al.*, 2005; Stahlman and Phillips, 1979). In this experiment, the spray-to-wet method (variable volume: more than 90 ml/plot) gave better *M. bracteata* kill compared to fixed volume spraying (90 ml/plot) in all the treatments and for all observation period (*Table 2*). Furthermore, means of the percentage of *M. bracteata* casualty for weeks 1, 5 to 6, 10 to 12, and 15 to 16 between variable and fixed spray volumes were significantly different with P values ranging from 0.001 (week 5) to 0.04 (week 12) through ANOVA-Fisher's LSD test at $P = 0.05$ (data not shown). Full coverage of herbicides on

M. bracteata leaves, namely variable spray volume or spray-to-wet method (> 90 ml/plot), was needed to provide good control of the legume.

Efficacy of Chemical Treatments

Multifactorial ANOVA indicated that live and dead/killed *M. bracteata* with herbicide treatments were significantly different from the control one week after each respective rounds of spraying, namely week 1, 5, 9, and 14 (*Table 2*). The variable 'herbicides' was found to be significant in terms of the coverage of live and dead/killed *Mucuna* (in the unit of percentage) a week after respective round of spraying (*Table 2*). All herbicide treatments caused various degrees of chlorosis and casualty to *M. bracteata* (*Table 3*). However, *M. bracteata* casualty was significantly higher for treatments with paraquat dichloride (PD), glyphosate isopropylamine+metsulfuron methyl mixture (GI+MM) and glufosinate ammonium (GA) compared to metsulfuron methyl (MM),

TABLE 2. PERCENT OF CASUALTY OR LIVE IN *Mucuna bracteata* ON ONE WEEK AFTER RESPECTIVE SPRAYING ROUND

Variable	% of *Mucuna* cover casualty				% of live *Mucuna* cover			
	Week 1	Week 5	Week 9	Week 13	Week 1	Week 5	Week 9	Week 13
	P	*P*	*P*	P	*P*	*P*	*P*	*P*
Replication	**	*	NS	NS	***	**	*	NS
Herbicide (H)	***	***	***	***	***	*	***	***
Volume (V)	*	***	**	NS	*	**	NS	NS
Frequency (F)	NS	***	*	*	NS	**	*	*
H x V	NS	NS	***	*	NS	NS	***	*
H x F	NS	***	***	NS	NS	***	***	*
V x F	NS	NS	NS	NS	NS	NS	NS	NS
H x V x F	NS	*	**	NS	NS	NS	**	NS

Note: Asterisks (*, **, and ***) illustrate significant effects at $P < 0.05$ with ANOVA-GLM (multifactorial analysis) techniques and means were separated with Tukey's test ($P < 0.05$). *P* values: < 0.05 (*), < 0.01 (**), and < 0.001(***) indicate statistically significant, moderately, and highly significant difference, respectively. NS refers to no significant difference.

TABLE 3. PERCENT OF *Mucuna bracteata* CASUALTY FOR THE TREATED AND CONTROL PLOTS

Treatment	% of *Mucuna bracteata* casualty* **							
	Week 1	Week 2	Week 5	Week 6	Week 9	Week 10	Week 13	Week 14
Untreated control (C)	0d	0e	0c	0f	0c	0d	0d	0e
Paraquat dichloride (PD)	51.7a	13.7ab	51a	26.3de	68.3a	61ab	4c	98.3a
Glyphosate isopropylamine + metsulfuran methyl (GI+MM)	35bc	16.3a	28.7ab	63.3ab	48a	60.3ab	27b	45.3b
Glufosinate ammonium (GA)	36.7b	10.3bc	48a	58.7abc	67.7a	86a	4.3c	84.7a
Metsulfuron methyl (MM)	25.7c	8.7bcd	17.7b	41.3bcd	9.3b	36.7bc	43.7a	38bc
Ammonium chloride (AC)	30bc	6.7cd	13.7b	37cde	8.3b	39.7bc	5.2c	20d
Glufosinate ammonium + DSMA (GA+DSMA)	34bc	10bc	38.3ab	68.3a	4b	52.3b	5c	22.3cd

Note: * Percents of *Mucuna* casualty on the respective weeks outlined above were obtained from the weekly census results. Only the means of *Mucuna* casualty (in %) for one and two weeks after each round of spraying were shown here.
** There were four rounds of chemical applications/sprayings, namely on weeks 0, 4, 8, and 12, and all the census were scored on first and second weeks after respective round of treatment. Means within the same column, followed by the same letter, are not significantly different at $P < 0.05$ with ANOVA-Fisher's LSD test.

ammonium chloride (AC), a mixture of glufosinate ammonium+DSMA (GA+DSMA), and untreated control (*Table 3*).

Among all the chemical treatments, ammonium chloride (AC) showed the lowest percentage in *Mucuna* casualty (*Table 3*). In a previous experiment, Aladesanwa and Oladimeji (2005) reported that ammonium sulphate (AS) can be incorporated into glyphosate-based herbicides as a surfactant to improve the weed control efficacy in oil palm plantation for controlling grasses and broadleaved weeds. However, when AC was used alone, the efficacy in controlling weeds or *M. bracteata* was low (*Table 3*). Even though treatments with GA or GI alone were reported to demonstrate better weed kill or mortality compared to PD in a number of previous studies (Mohamad *et al.*, 2010; Wibawa *et al.*, 2009), *M. bracteata* casualty for both of these chemicals were not significantly different in this experiment. Application of MM alone was significantly less effective in suppressing *M. bracteata* compared to a mixture of GI+MM at half rates each on weeks 2, 9, 13, and 14 (*Table 3*). The result is consistent with the observations highlighted by Chung and Chang (1990).

As expected, variable spraying rounds (re-application once the *Mucuna* cover was > 70%) elucidated significantly better *Mucuna* casualty and lower percent of live *M. bracteata* compared to fixed spraying rounds (monthly application) (*Table 2*). Therefore, spraying chemicals at fixed time may not be effective in controlling weeds and should not be practiced in the estates for some chemicals. All three factors (herbicide, volume and frequency) and the interaction between herbicide x volume x frequency had a significant influence on the percent of *M. bracteata* casualty on weeks 5 and 9 (a week after second and third rounds of spraying) (*Table 2*). Interactions between herbicide x volume and herbicide x frequency did illustrate a significant effect on percent of live *M. bracteata* on weeks 9 and 13 (a week after third and fourth rounds of spraying) (*Table 2*). However, there was no interaction between volume and frequency of sprayings (*Table 2*).

Management Decisions

Table 4 illustrates comparisons between six different treatments with the details on chemical cost per round of spraying per hectare, number of rounds applied, duration of *M. bracteata* control, and decisions on the rounds of spraying based on the variable spraying chemical volume (spray-to-wet technique). Both the treatments with AC and GA+DSMA were less effective, as these two treatments required five to six rounds of spraying, short *M. bracteata* control duration, relatively fast *M. bracteata* regeneration rates, and high chemical cost per round – RM 116 to RM 144 per round per hactare, respectively (*Table 4*). This could be due to low level of phytotoxicity in AC or its concentration was too low. Furthermore, DSMA was reported to have the selective capability in smothering crabgrass and some other grasses (Landry and Murphy, 2001; Rumburg *et al.*, 1960). In the combination of GA and DSMA, the dosage for both of these chemicals were reduced by half of the manufacturer's recommended rate; this might partially contribute to lower efficacy, especially control duration (*Tables 3* and *4*) (unpublished data). Although application of MM alone had the lowest chemical cost per round of spraying, its capability to suppress *M. bracteata* was less compared to a mixture of MM with glyphosate in terms of the number of rounds required and duration of *M. bracteata* control (*Table 4*). GA, used alone, was relatively expensive compared to PD and GI+MM mixture. Therefore, GA was proposed to be applied in alternated sequence with systemic herbicides, namely glyphosate or metsulfuron methyl (Chung and Chang, 1990) to improve weed or *M. bracteata* kill efficacy, as well as to reduce the total weed control cost. Among all the six treatments, GI+MM was the most promising option for managing *M. bracteata* because only two rounds of spraying were needed with the ability to keep *M. bracteata* under control for five to seven weeks (*Table 4*). Hence, MM+GI could be one of the best herbicide combinations for controlling *M. bracteata* in young immature oil palm fields. Signs of the dieback for *M. bracteata* were observed in the treatments with systemic MM application, both MM alone or MM+GI at half rates, and the effects were more prominent in the plots with fixed spraying rounds (monthly application) compared to variable spraying rounds (re-application of chemical as the *M. bracteata* covers were > 70%) (*Table 4*). Therefore, MM+GI with variable chemical volume (spray-till-wet technique) and variable spraying rounds (re-application as *M. bracteata* ground covers were > 70%) was the most efficient treatment and with reduced effects on *M. bracteata* regeneration.

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TABLE 4. CONTROL DURATION AND COST OF THE SIX DIFFERENT TREATMENTS FOR DECISION-MAKING CONSIDERATION

Herbicide	No. of spraying rounds		Duration of control (weeks)*		Control	Cost‡ (RM ha^{-1})	Decisions**	Remarks
	Fixed	Variable	Fixed	Variable				
Paraquat dichloride (PD)	4	4	2-4	2-3	Fixed = Variable	67.50	Fixed	*Mucuna* regeneration ~a month
Glyphosate isopropylamine + metsulfuran methyl (GI+MM)	4	2	3-4	5-7	Fixed < Variable	43.68	Variable	Dieback noted and longer duration of control compared to MM
Glufosinate ammonium (GA)	4	4	2-4	2-5	Fixed = Variable	100.65	Fixed	*Mucuna* regeneration ~a month
Metsulfuron methyl (MM)	4	4	1-4	4-5	Fixed < Variable	18.00	Variable	Dieback noted
Ammonium chloride (AC)	4	6	2	2-3	Fixed = Variable	116.64	Fixed	Very fast *Mucuna* regeneration
Glufosinate ammonium + DSMA (GA+DSMA)	4	5	2-3	2-3	Fixed = Variable	144.25	Fixed	*Mucuna* regeneration faster than full rate GA only

Note: * Duration of control (number of weeks) for both treatments with fixed No. of spraying rounds (monthly) and variable rounds of spraying (as *Mucuna* coverage is >70%).
** Decisions for using either fixed number of spraying rounds (monthly) or variable rounds of spraying (as *Mucuna* coverage is >70%).
‡ Cost (RM ha^{-1}) indicates total cost for the herbicide used per round in a hectare of oil palm plantations.

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