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Weed Control Efficacy and Short Term Weed Dynamic Impact of Three Non-Selective Herbicides in Immature Oil Palm Plantation

WAHYU WIBAWA, ROSLI MOHAMAD, ABDUL SHUKOR JURAIMI, DZOLKHIFLI OMAR†, M. GHAZALI MOHAYIDIN‡ AND MAHFUZA BEGUM[1]¶
Department of Crop Science, Faculty of Agriculture, UPM-43400 Serdang, Selangor, Malaysia
†*Department of Plant Protection, Faculty of Agriculture, UPM-43400 Serdang, Selangor, Malaysia*
‡*Department of Agribusiness and Information Technology, Faculty of Agriculture, UPM-43400 Serdang, Selangor, Malaysia*
¶*Fellow Researcher Institute of Tropical Agriculture, UPM-43400 Serdang, Selangor, Malaysia*
[1]Corresponding author's e-mail: mzap_27@yahoo.co.uk

ABSTRACT

Efficacy of three herbicides (paraquat, glufosinate ammonium & glyphosate) in immature oil palm plantation was evaluated. The experiment was quadruplicated in randomized complete block design with 13 treatments viz. paraquat at 200, 400, 600, 800 g a.i. ha^{-1}, glufosinate ammonium at 200, 400, 600, 800 g a.i. ha^{-1} and glyphosate at 400, 800, 1200, 1600 g a.i. ha^{-1} and an untreated check as control. Glufosinate ammonium and glyphosate were much better than paraquat as supported by data on weed mortality, weed dry weight, weed density and sum dominance ratio (SDR). Glufosinate ammonium and glyphosate also affected short-term weed dynamic and were found to be more suitable to control mixed weed in immature oil palm plantation.

Key Words: Glufosinate ammonium; Glyphosate; Oil palm; Paraquate; Weed control

INTRODUCTION

Herbicides offer the most practical, effective and economical means of managing weeds problems, thereby reducing crop losses and lowering production costs (Esterninos & Moody, 1988). The use of herbicides in Malaysian oil palm industry is predicted to be above 17.2 million liters in 2010 (Anonymous, 2004). Each herbicide has specific characteristics to control weeds due to its specific mode of action (Sani *et al*., 1991; Hoerlein, 1994). Among the many herbicides used in oil palm plantation paraquat, glyphosate and glufosinate-ammonium are most common. Paraquat is usually used as a contact herbicide, and is applied to the foliage (Ashton & Crafts, 1981; Collins, 1991; Turner & Gillbanks, 2003). Glufosinate-ammonium is a contact herbicide (Maschhoff *et al*., 2000; Neto *et al*., 2000), although Turner and Gillbanks (2003) stated that it systemically inhibitory activity. Glyphosate is categorized as a systemic herbicide and act as cell division and photosynthetic inhibitor (Caseley, 1994; Chang & Liao, 2002).

Weed populations, especially in cropped lands, are rarely constant, but are in dynamic state of flux due to changes in climatic and environment conditions, crop husbandry and the use of herbicides (Cobb, 1992; Al-Gohary, 2008a & b). Ideally, an herbicide should control all weeds equally well. Practically, however herbicides are specific in their effectiveness against some weeds than others. Shift in weed composition is a consequence of differential selection and effectiveness of herbicides (Wrucke & Arnold, 1985; Swanton *et al*., 1993). Effect of herbicides on short-term weed dynamic is important, but it is rarely assessed. Analysis of short-term weed dynamic can suggest reason for changes in population size or species composition over time. The consequences of various management practices, including selectioin of a proper herbicide, on weed community also can be analysed if such aspects are properly studied.

Several authors have studied herbicide efficacy for managing noxious weeds as *Asystasia intrusa, Mikania micrantha* (Kuan *et al*., 1991), *Hedyotis verticillata* (Pin & Leng, 1991), *Paspalum conjugatum* (Ipor & Price, 1991; Sani *et al*., 1991), *Imperata cylindrica* (Subagyo *et al*., 1991), *Axonopus compressus, Melastoma malabathricum, Mimosa pudica, Chromolaena odorata* (Sani *et al*., 1991; Ikuenobe & Ayeni, 1998). In agricultural systems a single weed is rarely found in any plantation and field condition. Commonly, oil palm plantations have weed flora comprising of few weed species. Uncertainty about weed species density, composition and change in population and community dynamics can lead to inappropriate management decisions (Radosevich *et al*., 1997). Moreover, the repeated

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use of the same herbicide year after year with sub-lethal doses shift the weeds from sub-noxious to noxious species including introduction of herbicide-resistant biotypes. An effort was made to evaluate the efficacy of three broad spectrum herbicides, paraquat, glufosinate-ammonium and glyphosate for reducing naturally occurring weed pressure and identify their effect on short-term weed dynamics in immature oil palm plantation.

MATERIALS AND METHODS

Experimental site and treatments. Field experiment was carried out at MAB Agriculture-Horticulture Sdn. Bhd. Sepang, Selangor during February–August, 2004 in a two-years old oil palm plantation. The soil was a sandy clay loam (32.28% clay; 7.11% silt & 60.58% sand) with pH 5.03, 1.14% organic C, 0.75 g kg^{-1} N, 0.05 g kg^{-1} P, 0.07 g kg^{-1} K, 0.02 g kg^{-1} Ca, and 0.03 g kg^{-1} Mg. The experiment was conducted in a randomized complete block design (RCBD) with 13 treatments replicated 4 times. Each plot measured 4.8 m × 20.5 m with including three oil palm plants. The treatments consisted of paraquat at 200, 400, 600, 800 g a.i. ha^{-1}, glufosinate-ammonium at 200, 400, 600, 800 g a.i. ha^{-1}, glyphosate at 400, 800, 1200, 1600 g a.i. ha^{-1}, and untreated plot as a control. Herbicide formulations used were Gramoxone® (200 g paraquat L^{-1}), Basta 15® (150 g glufosinate ammonium L^{-1}), and Roundup® (360 g glyphosate L^{-1}). Knapsack sprayer fitted with AN 2.5 deflector nozzle was used to deliver 200 L ha^{-1} of herbicide solution. Spray calibration was conducted to determine forward speed, spray width (swath), flow rate and application rate as described by Caseley (1994) and Turner and Gillbanks (2003).

Initial vegetation analysis. Naturally occurring weed population were used in the experiment. The experimental area was divided into 4 strata, which represented blocks in the experimental design. Square method was used to identify weed parameters using 0.5 by 0.5 m quadrat. Weed samples were collected by randomly placing a 0.5 by 0.5 m quadrat at 10 locations per stratum. Absolute and relative weed densities, frequencies and dominance of each weed type were recorded to compute sum dominance ratio (SDR), community coefficient (CC). Destructive method was used to compute weed dominance. All above ground weed vegetations were harvested and separated by weed type; sun dried for 4 days and than dried in an oven at 75°C for 48 h and their dry weight was recorded (Felix & Owen, 1999). Community coefficient values indicated homogeneity or similarity among the weed communities. According to Bonham (1989) CC value >71% (good to excellent homogeneity) is a required condition for carrying out weed control experiment.

Parameters for percent weed killed, weed density and weed dry weight. Weed sampling was done by randomly placing a 0.5 m × 0.5 m quadrat at 3 locations in each experimental unit. Weed mortality at 2 and 4 weeks after treatment (WAT) and weed density and weed dry weight at 8, 12 and 16 WAT were computed.

Non-destructive sampling was used to record weed mortality and weed density and were grouped into broadleaved and grass weeds for analysis. Control of foliage was assessed by counting of shoot number or number of plant killed for each weed type relative to the numbers of each weed type present (Alloub *et al*., 2000; Pritchard. 2002). Plants killed meant that all tissues from growing point to the soil surface were completely dead. Destructive method was used to evaluate weed dry weight as described earlier.

Sum dominance ratio (SDR). The major or dominant weed species were determined by computing SDR values (Sukarwo, 1991) as follows:

SDR of a sp. =

$$\frac{\text{relative density} + \text{relative frequency} + \text{relative dominnce}}{3}$$

Relative density, relative frequency and relative dominance were measured from the following:

Relative density of a sp. =

$$\frac{\text{Absolute density of a sp.}}{\text{Total absolute density of all spp.}}$$

Relative dominance of a sp. =

$$\frac{\text{Absolute dominance of a sp.}}{\text{Total absolute dominance of all spp.}}$$

Relative frequency of a sp. =

$$\frac{\text{Absolute frequency value of a sp.}}{\text{Total absolute frequency value of all spp.}}$$

Absolute density of a species was equal to total number of plants of that species in the sample plot, absolute dominance of a species was the total biomass of that species in the sample plot.

Absolute frequency of a species =

$$\frac{\text{number of plots containing the sp}}{\text{total sample plots}}$$

Community coefficient (CC). Community coefficient was computed as suggested by Tjitrosoedirdjo *et al.* (1984) and Bonham (1989).

Where:

$$CC = \left(\frac{2w}{a} + b\right) * 100$$

CC=community coefficient,

W = total of the lowest SDR value of all species from each community:

A = total of all SDR values from the first community and

B = total of all SDR values from the second community.

CC values indicated homogeneity of weed communities among the herbicides. Bonham (1989) divided vegetation condition into 5 classes, namely, excellent (91-

100%), good (71-90%), fair (56-70%), poor (45-55%) and unacceptable (<45%).

Statistical analysis. The data were analyzed by using SAS package (SAS Institute Inc., 1996) for analysis of variance (ANOVA) and significant differences were tested using Tukey's studentized range test at the 5% level of probability.

RESULTS AND DISCUSSION

Initial vegetation analysis. In all 33 weed species were recorded in the experimental area of immature oil palm plantation. About 80% of the total weeds comprised of only 10 weed species, namely, *Croton* sp., *Asystasia intrusa*, *Centrosema pubescen*, *Borreria latifolia*, *Ageratum conyzoides*, *Hedyotis verticillata*, *Calopogonium mucunoides*, *Cleome rutidosperma, Paspalum commersonii* and *Pennisetum polystachion* (not shown). Community coefficient values at initial vegetation analysis showed that weed homogeneities ranged from 75.14 to 82.03% and these vegetation conditions were classified as good condition to conduct weed control experiment (data not shown). A homogeneity more than 71% (Bonhan, 1989) and 75% (Tjitrosoedirdjo *et al.*, 1984; Sukarwo, 1991) are the required conditions to carry out weed control experiment. More this indicated that naturally occurring weeds in the field had uniform weed growth proving a suitable condition to carry out experiment.

Effect of herbicides on the weed mortality. Weed mortality was a good indicator to determine the efficacy of herbicide applied. Paraquat application had lower level of control than glufosinate-ammonium and glyphosate at 2 and 4 WAT (Table I). Burrill *et al*. (1976) stated that 70% weed mortality is the minimum acceptable level of control and >90% being the excellent. Paraquat at 400, 600 and 800 g a.i ha^{-1} effectively controlled broadleaf weeds but at 200 g a.i. ha^{-1} only 59.68% weed mortality was recorded. Application of paraquat at 200 g a.i. ha^{-1} did not effectively control 7 broadleaf weed species namely, *A. intrusa*, *H. verticilata*, *B. latifolia*, *B. repens*, *C. mucunoides*, *C. pubescen* and *S. indica* (not shown). Paraquat application at 200, 400, 600 and 800 g a.i ha^{-1} were not effective (38.35-69.87%) in controlling grassy weeds at 2 and 4 WAT. Ashton and Crafts (1981) stated that paraquat is not considered to be selective herbicide, although broadleaf plants were injured somewhat more than grasses at a given low rate. Collins (1991) also reported that paraquat has limited efficacy on perennial weeds but is more effective on weeds, which are small and in early establishing or vegetative phase of growth. Some annual grasses may only be temporarily suppressed, because the low and enclosed growing points are not contacted by the spray. Turner & Gillbanks (2003) stated that the greatest paraquat efficacy is found where the weed species to be controlled have restricted root system or are still young.

All application rates of glufosinate-ammonium in these studies effectively controlled both broadleaved and grass weeds at 2 and 4 WAT except 200 g a.i. ha^{-1} to control grasses at 2 WAT (Table I). Turner and Gillbanks (2003) stated that glufosinate-ammonium has systemic activity, while according to Collins (1991) it is partially systemic. Glufosinate-ammonium was very effective to control broadleaved and grass weeds. This herbicide has been recommended for plantation use at rates of 300 to 800 g a.i ha^{-1}, but also often applied at various rates from 140 to 1500 g of a.i. ha^{-1} (Hoerlein, 1994).

Glyphosate application at 400, 800, 1200 and 1600 g a.i ha^{-1} excellently controlled both broadleaved and grass weed at 2 WAT and 4 WAT (Table I). Collins (1991) stated that glyphosate is a systemic herbicide and it is much more effective against weeds with well-developed root system or underground storage organs. Low application rate of 370 g ha^{-1} has sometimes been used to remove grass and broadleaf weeds without adverse effects for immature oil palm as long as it was not sprayed directly to the plant (Turner & Gillbanks, 2003). Kataoka *et al.* (1996) found that the complete translocation of this herbicide confers remarkable efficacy on most weeds, whether they are annual broadleaves and grasses, perennial broadleaves and grasses or sedges.

Effect of herbicides on weed dry weight. Application of paraquat, glufosinate-ammonium and glyphosate significantly reduced dry weight of broadleaf weeds and grasses at 8, 12 and 16 WAT (Table II). Paraquat at all doses produced more dry weight in broadleaf weeds and grasses, while higher grass weed dry weights were recorded for glufosinate-ammonium and glyphosate at 8 WAT. Paraquat at 200, 400, 600 and 800 g a.i ha^{-1} reduced the dry weight in broadleaf weeds more than grasses at 8, 12 and 16 WAT. On the other hand, glufosinate-ammonium and glyphosate reduced weed dry weight of broadleaf weeds and grasses almost similar at 8, 12 and 16 WAT. This was owing to poor ability of paraquat in controlling the grassy weeds. Collins (1991) reported that paraquat had limited efficacy on perennial weeds and some annual grasses may only be temporarily suppressed. Daubenmire (1968) observed that weed dry weight showed productivity of weed community measured and indicated the level of weed growth. Weed community treated by paraquat grew and recovered faster than glufosinate-ammonium and glyphosate as indicated by weed dry weight produced.

Effect of herbicides on weed density. Paraquat, glufosinate-ammonium and glyphosate application did not affect grass weed densities at 12 and 16 WAT (Table III). At 8 WAT, broadleaf and grass weed densities were significantly affected by treatments. Paraquat did not significantly affect both types of weed densities indicating similar weed densities with the untreated plots. Glufosinate-ammonium and glyphosate application recorded an increaseed broadleaf weed densities at 8 WAT even though it was continuous increasing up to 12 and 16 WAT. Effect of glufosinate-ammonium and glyphosate was insignificant between each other implying

Table I. Effect of paraquat, glufosinate-ammonium and glyphosate on percent weed mortality

Treatment	Dose (g ha^{-1})	2 WAT		4 WAT	
		Broadleaved	Grasses	Broadleaved	Grasses
Untreated check	-	0.00g	0.00g	0.00f	0.00f
Paraquat	200	59.68f	38.35f	59.95e	38.35e
Paraquat	400	81.80e	54.29ef	83.72d	54.29d
Paraquat	600	87.80de	66.15cde	87.80d	66.15d
Paraquat	800	87.47de	65.71de	89.14cd	69.87d
Glufosinate-ammonium	200	94.68bcd	59.65de	96.07abc	85.61c
Glufosinate-ammonium	400	95.04cd	74.41cd	97.96abc	93.94bc
Glufosinate-ammonium	600	97.53abc	89.58b	97.87ab	98.07ab
Glufosinate-ammonium	800	99.52ab	82.68bc	99.52a	96.39ab
Glyphosate	400	91.25de	72.33cde	92.40bcd	98.94ab
Glyphosate	800	99.38ab	97.95a	100.00a	100.00a
Glyphosate	1200	98.90abc	98.69a	99.46a	100.00a
Glyphosate	1600	100.00a	100.00a	100.00a	100.00a

*Means within columns followed by the same letter are not significantly different at 5 % by the DMRT

Table II. Effect of paraquat, glufosinate-ammonium and glyphosate on weed dry weight

Treatment	Dose (g ha^{-1})	Weed dry weight (g 0.25 m^{-2})*					
		8 WAT		12 WAT		12 WAT	
		Broadleaved	Grasses	Broadleaved	Grasses	Broadleaved	Grasses
Untreated check	-	33.96 a	26.92a	30.35	42.87a	32.76	43.46 a
Paraquat	200	18.19 ab	24.36a	19.41	25.31ab	24.10	42.43a
Paraquat	400	15.07 ab	18.67a	17.13	27.29ab	26.17	41.70a
Paraquat	600	10.87 b	17.14a	13.96	25.93ab	29.14	33.57ab
Paraquat	800	9.77 b	11.6ab	18.28	14.12b	32.86	25.90ab
Glufosinate-ammonium	200	8.94 b	4.00bc	18.40	3.66cd	33.80	8.19bc
Glufosinate-ammonium	400	9.46 b	2.40cd	16.40	4.18c	33.12	11.39abc
Glufosinate-ammonium	600	10.72 b	1.77cd	17.04	3.42cd	33.64	10.90abc
Glufosinate-ammonium	800	12.15 b	2.67c	16.65	4.95c	33.11	12.14bc
Glyphosate	400	12.01 b	1.53cd	20.65	1.64cd	35.74	9.74bc
Glyphosate	800	9.25 b	1.74cd	17.29	3.70cd	41.28	4.65c
Glyphosate	1200	9.62 b	2.06cd	19.39	2.32cd	38.45	3.54c
Glyphosate	1600	12.03 b	0.37 d	20.00	1.24d	1.24d	4.67c

Means within column followed by the common letter are not significantly different at 5% level by the DMRT

Table III. Effect of paraquat, glufosinate-ammonium and glyphosate on weed density

Treatment	Dose (g ha^{-1})	Weed dry weight (g 0.25 m^{-2})*					
		8 WAT		12 WAT		12 WAT	
		Broadleaved	Grasses	Broadleaved	Grasses	Broadleaved	Grasses
Untreated check	-	42.00abcd	22.08a	32.75cd	25.84	34.67cde	29.58
Paraquat	200	22.08cd	20.11a	29.67d	17.25	25.92e	25.75
Paraquat	400	32.42bcd	19.59a	36.92bcd	24.42	30.50cde	29.34
Paraquat	600	29.72d	18.25a	28.00d	23.50	35.00de	24.25
Paraquat	800	30.83bcd	21.50a	43.25abcd	15.00	38.84bcde	29.00
Glufosinate-ammonium	200	61.59abc	17.17a	73.25ab	11.58	52.42abcd	10.92
Glufosinate-ammonium	400	63.09ab	11.34a	66.50 ab	13.00	62.75abcd	12.83
Glufosinate-ammonium	600	69.67a	9.42ab	65.00ab	14.42	64.08abc	15.75
Glufosinate-ammonium	800	63.84ab	13.59a	55.67abc	25.58	47.17abcd	24.83
Glyphosate	400	67.83ab	8.08ab	72.67ab	6.67	61.84abc	16.00
Glyphosate	800	59.83ab	9.67ab	70.83ab	11.00	63.25abc	13.00
Glyphosate	1200	56.42abc	10.83a	69.34ab	12.58	70.33ab	10.00
Glyphosate	1600	73.25a	2.67b	88.58a	8.58	83.83a	4.42

their similar ability to affect weed densities.

In general, untreated plots and paraquat application had lower broadleaf weed densities than glufosinate-ammonium and glyphosate treatments. Plots treated with gluphosinate-ammonium and glyphosate had higher broadleaf weed densities than paraquat treatments at 8, 12 and 16 WAT. At 8 WAT, glyphosate at 1600 g a.i. ha^{-1} reduced grass weed density significantly that became insignificant at 12 and 16 WAT giving very low numerical values. In this study, paraquat, glufosinate-ammonium and glyphosate treatments did not affect grass weed densities significantly at 12 and 16 WAT although these treatments had significantly good weed mortality and reduced weed dry weights suggesting that efficacy of weed control could not be directly explained by weed density, because weed community was complex.

Table IV. Effect of paraquat, glufosinate-ammonium and glyphosate on the SDR (%)

Treatment	Dose (g ha^{-1})	8 WAT		12 WAT		12 WAT	
		Broadleaved	Grasses	Broadleaved	Grasses	Broadleaved	Grasses
Untreated check	-	64.57	35.43	55.76	44.24	56.42	43.58
Paraquat	200	53.58	46.42	58.13	41.87	50.45	49.55
Paraquat	400	61.35	38.65	56.24	43.76	53.88	46.12
Paraquat	600	57.33	42.67	50.69	49.31	58.99	41.01
Paraquat	800	60.36	39.64	68.99	31.01	59.63	40.37
Glufosinate-ammonium	200	72.97	27.03	81.33	18.68	80.38	19.62
Glufosinate-ammonium	400	82.55	17.45	77.53	22.47	77.78	22.22
Glufosinate-ammonium	600	83.09	16.91	78.10	21.90	73.72	26.28
Glufosinate-ammonium	800	80.26	19.74	71.41	21.89	70.50	29.50
Glyphosate	400	88.91	11.09	87.83	12.17	77.78	22.22
Glyphosate	800	83.40	16.60	82.38	17.62	85.14	14.86
Glyphosate	1200	81.50	18.50	82.45	17.55	85.35	14.65
Glyphosate	1600	94.26	5.74	88.12	11.90	87.80	12.20

Effect of herbicides on SDR. Commonly, fast regeneration through seed germination and incomplete weed killed was the main factor causing weed species to be major weeds in the community. Dominance between broadleaf and grass weeds at untreated plots and paraquat treated plots were still proportional, although dominance of broadleaf weeds were always rather a little bit higher than dominance of grass weeds (Table IV). Plots treated with glufosinate-ammonium and glyphoset had more dominance of broadleaf weeds than grass weeds. Dominance of weed group is affected by density, frequency and productivity of weed community. Active ingredients of herbicides had different mode of action and certain characteristics to express their efficacy. Most herbicides are somewhat more effective against some weeds than against other. In this study, regeneration may be from incompletely killed (perennial & grass weeds) dominated on the community treated with paraquat, while the community treated with glufosinate-ammonium and glyphoset were dominated by weeds germinating from seed-bank.

Effect of herbicides on weed shifting. Differential effectiveness of herbicides applied could cause shift in weed composition, which then affect their similarity (Wrucke & Arnold, 1985; Swanton *et al*., 1993). Weed shifting was identified based on the CC values at 8, 12 and 16 WAT. CC values of less than 56 % meant that the similarities were poor to unacceptable, and it was assumed that weed shifting occurred in weed community (Table V).

Regeneration from incomplete kill of perennial and grass weeds are responsible for CC values among the untreated check and paraquat treatments to be still high at 8, 12 and 16 WAT, respectively. Most of the grassy weed species still dominated in the weed community so that weed shifting did not occur. On the other hand, treatments with glufosinate-ammonium and glyphosate produced good to excellent efficacy to control grassy weeds and caused shifting in weed composition, which then affected their poor similarity to untreated check at 8, 12 and 16 WAT. The SDR comparison between paraquat with glufosinate-ammonium and paraquat with glyphosate gave lower CC values, which indicated that different weed composition existed among these treatments. Glufosinate-ammonium and glyphosate treatments changed weed composition from being grasses to broadleave weeds, which were easier to control. There were two advantages in using glufosinate-ammonium and glyphosate. They were very effective to control mixed weeds and stimulated shifting weeds, which is easy to control in immature oil palm plantation.

Table V. Effect of three herbicides on community coefficient at 8, 12 and 16 WAT

Treatments	Community coefficient (%)		
	8 WAT	121 WAT	16 WAT
Untreated : Paraquat	70.08	78.05	74.74
Untreated: Glufosinate-ammunium	48.98	42.89	52.23
Untreated: Glyphosate	41.94	34.40	40.70
Paraquat: Glufosinate-ammunium	46.26	47.80	52.63
Paraquat : Glyphosate	37.50	41.45	43.02
Glufosinate-ammunium: Glyphosate	76.78	78.93	74.05

CONCLUSION

Significant differences were observed amongst the treatments in percentage weed mortality and weed dry weight and density. Glufosinate-ammonium and glyphosate were better to control grasses than broadleaf and more suitable to control mixed weed in immature oil palm plantation. Community coefficient values of less than 56% after herbicide application indicated that the similarities were poor and weed shifting occurred due to efficacy of applied herbicide.

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