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Evaluation of metsulfuron-methyl and combinations in controlling weeds in juvenile oil palm plantation

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Abstract

Herbicide mixtures provide good control at considerably lower dosages than dosages utilized in single applications. A study was conducted at the Benso Oil Palm Plantation to evaluate the efficacy of application of sole Metsulfuron-Methyl (a residual sulfonylurea herbicide) and its combinations with Glisat (glyphosate) in controlling weeds under two-year old oil palm. The sole Metsulfuron-Methyl application rates were a) 190.5g/ha; b) 381g/ha, c) 571.4g/ha or in combination with Glisat at rates d) Metsulfuron-Methyl at 190.5g/ha + Glisat at 2.8 l/ha, e) Metsulfuron-Methyl at 190.5g/ha + Glisat at 4.3 l/ha and Metsulfuron-Methyl at 381g/ha + Glisat at 2.8 l/ha; Metsulfuron-Methyl at 381g/ha + Glisat at 4.3 l/ha. No chemical treatment (water) and Ceresate at 1.5 L/ha served as the control treatments. Application of sole Metsulfuron-Methyl or in combination with Glisat significantly reduced weed dry weight. The reduction in weed weight was more pronounced at 4 weeks after treatment. The sole Metsulfuron-Methyl application was less effective in controlling weeds than Ceresate or Metsulfuron-Methyl and Glisat combinations. Herbicide efficacy recorded for Metsulfuron-Methyl sole at different rates at 4 WAT ranged from 64 to 75% for broadleaves and 35 to 40% for grasses. The combined application of Metsulfuron-Methyl and Glisat was effective in controlling both broadleaves and grasses. Metsulfuron-Methyl sole or in combination with Glisat had no adverse effect on oil palm growth and significantly improved vegetative parameters. A combined application of Metsulfuron-Methyl at 190.5 g/ha and Glisat 2.8 L./ha is recommended in controlling both broadleaves and grasses under oil palm plantations.

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Introduction

Weeds are a major component in oil palm production system. The composition of weeds is a mixture of grasses, sedges, and broadleaves which often changes according to the crop growth stages which provide specific climatic and environmental conditions suitable for specific weed growth (Mohamad *et al.*, 2010). Young oil palm trees are more sensitive to competition from weeds, because weeds have a tendency of overgrowing the crop if they are not controlled early in the growth period. Weeds in oil palm plantation are managed using several methods such as biological (legume cover crops), slashing, mechanical, integrated production system of using livestock to control the weeds, or chemical (herbicides). Chemical weed control is recognized to be an economical practice in of oil palm plantations (Hornus, 1990) and it can reduce reliance on manpower for hand weeding.

Effect of herbicides on short-term weed dynamics is important, but it is rarely assessed. Analysis of short-term weed dynamics can suggest reason for changes in population size or species composition over time. The consequences of various management practices, including selection of a proper herbicide, on weed community also can be analyzed if such aspects are properly studied. Uncertainty about weed species density, composition and change in population and community dynamics can lead to inappropriate management decisions (Radosevich *et al.*, 1997).

Several common broad-spectrum herbicides are available on the Ghanaian market. Among these herbicides are different formulations of glyphosate which are commonly used in Ghana and is able to control a broad spectrum of weeds and some work have already being done on glyphosate use in Ghana (Oppong *et al.*, 1999, Baidoo- Addo *et al.*, 2000, Larbi *et al.*, 2013). However Glyphosate is not highly effective on some few weeds like *Commelina erecta* and *Asystacia gangetica* as well as a broad range of woody growths, hence the need to explore the use of other herbicides used elsewhere. Metsulfuron-Methyl is a residual sulfonylurea herbicide that kills both broadleaf weeds and some annual grasses. It is used for pre- and post-emergent selective broadleaf treatment (Hussain *et al.*, 2003). Glisat is a trade name of glyphosate, a broad spectrum herbicide that is often used to control weeds under oil palm (Wibawa *et al.*, 2009).

The combination of two or more herbicides in tank-mixtures could reduce application cost (Lich *et al.*, 1997) and delay the occurrence of resistance to both herbicides applied in the combination (Diggle *et al.*, 2003). Herbicide mixtures are also commonly used in agriculture to broaden the spectrum of weed species that can be controlled. In some situations, mixtures or combinations provide good control at considerably lower dosages than dosages utilized in single applications (Lynch *et al.*, 1970).

Tewari *et al.* (1998), evaluated the efficiency of Metsulfuron-Methyl on associated weeds in wheat and attributed the higher yield to less competition between weeds and wheat plants for various growth factors. Herbicides containing glyphosate and Metsulfuron-Methyl has also been used in controlling environmental weeds (Toth and Winkler, 2008) such as bitou (*Chrysanthemoides monilifera* subsp. *rotundata* (DC) T. Norl.) and Toth *et al*, (1996) reported adverse impacts of the herbicides on some native species.

To date, information on research using tank mixtures of Metsulfuron-Methyl and glyphosate for control of mixed weeds spectrum under young oil palm and its impact on the crop is limited. This study was carried out to determine whether 1) sole or tank- mix combinations of Metsulfuron-Methyl with glyphosate could provide control of mixed weed spectrum under young oil palm plantation and 2) the effects of the herbicide treatments on the growth of young oil palm.

Materials and methods

Experimental site

The experiment was conducted at the Benso Oil Palm Plantation at the Adum Banso estate (6°05’ N; 0 ° 05’ W), located 175 km north-west of Accra in the forest zone of Ghana. The area is characterized by bi-modal rainfall distribution with a mean annual rainfall of 1645mm. Temperatures are generally high and fairly uniform throughout the year. Mean monthly temperatures range from 24 – 30 °C. The relative humidity is generally high in the morning, about 90%, at 0600 hours and reducing to between 60 and 70% in the afternoon (1500 hours). Generally, in the wet season relative humidity is high (about 95%), but low (about 40%) in the dry season. Some chemical properties of soil used which belongs to the Omappe series are as follows: pH (1:1 soil: water)= 5.10, total N= 0.18%, Available P= 12.10 mg/kg, Available K = 200.87 mg/kg, Organic carbon = 2.36%, ECEC = 3.52cmol/kg). The study was conducted on a two year old oil palm (D x P) variety plantation planted at a density of 145 palms ha^{-1}.

Experimental design

The experimental plot size of 5m x 21m was set up. Nine treatments were adopted as follows: Metsulfuron-Methyl at a) 190.5 g ha^{-1}, b) 381 g ha^{-1} and c) 571.4 g ha^{-1}) and d) Ceresate 1.5 L ha^{-1} (recommended rate) and (e) untreated control plots (water only) in a randomized complete block experimental design with four replications. The combined herbicide treatments were f) Metsulfuron-Methyl at 190.5 g/ha + Glisat at 2.8 l/ha, g) Metsulfuron- Methyl at 190.5 g/ha + Glisat at 4.3 l/ha, h) Metsulfuron- Methyl at 381 g/ha + Glisat at 2.8 l/ha and i) Metsulfuron-Methyl at 381 g/ha + Glisat at 4.3 l/ha.

Initial vegetation analysis

Weed samples were collected by randomly placing a 0.5 by 0.5 m quadrant at 10 locations per stratum. Weeds were counted in 3 quadrates to determine their species, density and dominance of each species expressed in relative terms, using the formula below (Derksen *et al.,* 1993):

$$\text{Relative (X) of a species} = \frac{\text{Absolute (X) of the species}}{\text{Total absolute (X) of all species}}$$

where, X = density or dominance

All the above ground weed vegetation were harvested and separated by weed type; sun dried for 4 days and dried in an oven at 80°C for 48 hours and their dry weight was recorded (for dominance evaluation) (Felix and Owen, 1999).

Effects of herbicides on weed population

The square method was used to determine the effects of the herbicides on total weed population measured as the percentage of weed killed, weed dry weight, growth reduction and duration of their effective control of the weeds relative to the control treatment. Destructive and non destructive samples were taken using the quadrat at weekly intervals after treatments (WAT). The criteria used were: species killed (complete brown leaves), chlorotic (yellowing), still remaining green (alive). Plants killed meant that all tissues from growing point to the soil surface were completely dead. The weed dry weight was determined by drying in an oven at 80°C for 48 hours.

The percent growth reduction is the ability of a treatment to suppress weed growth and was calculated using the formula (Chuah *et al.*, 2004):

$$\%\ \text{growth reduction} = \frac{\text{Dry weight from treated plot}}{\text{Dry weight from untreated plot}} \times 100$$

The efficacy (E) of herbicide by mass of weeds was calculated by the following formula:

$$E = \frac{M1 - M2}{M1} \times 100$$

Where;

M_1 = Weed mass per m^2 on untreated plots;

M_2 = Weed mass per m^2 on plots treated with herbicides. (Auskalnis, 2003).

Effects of herbicide on oil palm growth

The effect of herbicide residues on oil palm growth were determined based on the oil palm plant height, number of frond by each plant relative to the control treatment. Plant height and number of fronds were recorded for each crop plant within each plot before treatment application and at every 2 week intervals until 16 WAT. Plant height was measured from the soil surface to the highest part of fully opened frond. The number of frond was counted from the base of the fresh-green to the first fully-opened frond. Rachis length was determined by measuring with a tape measure, the length from the point of insertion of the lowest rudimentary leaflets (the last leaflets) to the tip where the last pair of differentiated leaves is attached. The spread of canopy was taken in two directions, east-west and north-south, with a measuring tape and the average calculated.

Statistical analysis

Data generated was subjected to statistical analysis. The Genstat statistical software was used for the analysis of variance. The treatment effects were tested by analysis of variance. The least significant difference was used to separate the means at 5% significance level.

Results and discussion

Initial vegetation analysis and Shifting in weed species population

Eleven weed species were dominant in the experimental area which consisted of a composite of mixed weeds of broadleaves and grasses, with broadleaves being more dominant over the grasses. The broadleaf weeds include, *Aspillia africana, Pueraria phaseoloides, Justicia flava, Ageratum conyzoides, Solanum Torvum, Asystacea gangetica, Diplazium sammatii, Baphia nitida and Melanthera scandens*. The dominant grass species at the site was *Panicum lineatum* (Table 1). The weed species observed at the site has been reported earlier (Essandoh *et al.*, 2011) as dominant weed species under young oil palm plantations in Ghana. The absence *of Chromolaena odorata* a notorious weed (Essandoh *et al.,* 2011) at the site, and the high dominance of *Pueraria phaseoloides* indicates earlier planting of *Pueraria* by the company. *Pueraria phaseoloides* is normally used as a cover crop in managing weeds under oil palm and also to improve on the soil fertility through biological nitrogen fixation. The dominance of the broadleaves is reflected in their total relative abundance of 62% and relative dominance of 72%. For the broadleaves *Pueraria phaseoloides*, was the most dominant species with relative dominance of 22% followed *Justicia flava* and then *Diplazium sammatii* (Table 1). The grass species *Panicum lineatum* was the most dorminant and abundant species followed by the broadleaf species *Pueraria phaseoloides* (Tables 1 and 2). The least dominant species include *Asystacea gangetica*. The situation, therefore, calls for the use of general post- emergent herbicides for chemical weed management in the locality (Mohamad *et al.*, 2010).

Table 1. Relative dominance of dominant weed species at the experimental site at different stages of experiment.

Weed species	Type*	Before treatment	4 WAT	16WAT
Justicia flava	B	10	17.18	13.28
Commelina erecta	B	7	3.78	10.38
Aspillia africana	B	4	0.28	3.32
Melanthera scandens	B	4	1	2.81
Panicum lineatum	G	28	38.78	36.43
Pueraria phaseoloides	B	22	17.96	19.08
Baphia nitida	B	3	9.61	3.40
Diplazium sammatii	B	13	10.41	2.0
Solanum torvum	B	3	0	4.03
Ageratum conyzoides	B	4.40	0.41	3.90
Asystacia gangetica	B	0.6	0.60	1.29
LSD ($P \leq 0.05$)		1.11	0.90	0.84

*B: broadleaf; G: grass.

Shifting in weed species population was observed at the different weeks after herbicide treatment with changes in relative dominance and abundance of some species (Tables 1 and 2) at different stages. The relative dominance of grass weed *Panicum lineatum* increased from 28% at the before treatment stage to 38.78% at 4 WAT whiles the relative dominance of *Justicia flava* also increased from 10% to 17.18% at

4WAT. For most species like *Pueraria phaseoloides* a decrease in relative dominance was observed at 4WAT. Differential effect of herbicides applied could cause shifting in weed population (Wibawa *et al.,* 2009). Sole Metsulfuron-Methyl was more effective on broadleaf species than on grasses. The woody species *Baphia nitida* was not controlled by any of the herbicide treatments. The relative dominance of most weeds reduced considerably at 4 WAT except *Diplazium sammatii* whose control was very slow at 4 WAT (Table 1) but was finally controlled from 8 WAT. Shifting in weed population was also observed at regrowth at 16 WAT. Weeds like *Commelina erecta* dominated other weeds at the site at 16 WAT. Compared to the relative dominance at the 4 WAT stage the dominance of *Commelina erecta*, increased by 100% at 16WAT (Table 2). The faster regrowth rate of *Commelina erecta* may be due to the relatively lower effect of herbicides on this species. Other dominant species at 16 WAT include *Ageratum conyzoides* and *Solanum torvum* (Tables 1 and 2).

Table 2. Relative abundance of dominant weed species at the experimental site at different stages of experiment.

Weed species	Type*	Before treatment	4 WAT	16WAT
Justicia flava	B	13.62	17.79	11.26
Commelina erecta	B	3.51	0.74	12.23
Aspillia africana	B	4.06	1.10	3.29
Melanthera scandens	B	3.24	2.10	2.35
Panicum lineatum	G	37.59	48.17	43.67
Pueraria phaseoloides	B	17.25	14.72	15.30
Baphia nitida	B	1.57	4.94	1.57
Diplazium sammatii	B	10.19	9.13	1.10
Solanum torvum	B	3.45	0	4.39
Ageratum conyzoides	B	3.21	0.23	4.55
Asystacia gangetica	B	2.54	0.24	1.57
LSD ($P \leq 0.05$)		0.84	0.98	1.09

*B: broadleaf; G: grass.

Effect of herbicide treatment on weed dry weight

Application of Metsulfuron-Methyl sole or in combination with Glisat significantly reduced dry weight of weeds at 4, 8 and 16 WAT with the effects been more pronounced at 4WAT (Table 3), indicating the effectiveness of the treatments in reducing the growth of the weeds compared to the untreated plot**.** However the effect of the treatments differed depending on the type of weed. Application of Metsulfuron-Methyl at all rates 190.5g /ha, 381g/ha and 571.4g/ha, reduced weed dry weights by 60%, 61% and 70% respectively over the control at 4 WAT. This high percentage weed reduction was due to the control of broadleaf weeds such as *Asystasia gangetica* and *Solanum torvum* by sole Metsulfuron-Methyl but was less effective in controlling the dominant grass species *Panicum lineatum*. The combined Metsulfuron-Methyl and Glisat application was however more effective in controlling a wider range of broadleaves and grasses at the experimental site. The combined application of Metsulfuron-Methyl at 190.5g/ ha and Glisat at 2.8l/ha reduced weed biomass by 95% at 4 WAT. This could be due to a better synergy obtained by the mixing the Metsulfuron-Methyl and Glisat herbicides. Application of Ceresate at 1.5 L/ha reduced weed dry weights by 92% at 4WAT. The combined application of 381 g/ha Metsulfuron-Methyl and 4.3 l/ha Glisat induced a marked 97% reduction in weed dry weight. Weed dry weights increased by 34% at 4WAT for the untreated plot. The results indicate that the combined use of Metsulfuron-Methyl and Glisat may have a higher effect in reducing the variety of weed species at the site than separate use of each herbicide. This result is similar to earlier observations of Wibawa *et al.* (2009) and Mohamad *et al.* (2010) who observed similar reductions in weed dry weight when they applied different broad spectrum herbicides and also when combined or mixed-tank herbicide were applied (Toth and Winkler, 2008).

Table 3. Weed dry weight and growth reduction after treatments with Metsulfuron-Methyl and Combinations.

Treatments	Dry weight (g/0.5m2)*				Growth reduction (%)*		
	0 WAT	4 WAT	8 WAT	16 WAT	4 WAT	8 WAT	16 WAT
Metsulfuron 0.0g/ ha	172	230	242	274	0	0	0
Metsulfuron190.5g/ ha	265	92	108	165	60	55	40
Metsulfuron 381.0 g/ ha	266	88	106	157	62	56	43
Metsulfuron 571.4 g/ha	126	69	100	152	70	58	45
Ceresate 1.5l / ha	155	19	46	146	92	81	47
Metsulfuron 190.5g/ ha + Glisat 2.8l/ha	225	11	39	137	95	84	50
Metsulfuron 190.5g/ ha + Glisat 2.8l/ha	128	10	30	129	95	88	53
Metsulfuron 381g/ ha + Glisat 2.8l/ha	93	8	14	100	97	94	63
Metsulfuron 381g/ ha + Glisat 4.3l/ha	105	3	4	41	99	98	85
LSD ($P \leq 0.05$)	4.28	1.01	1.04	4.33	1.83	1.70	1.21

The percentage of weed growth reduction and duration of effective weed (Mohamad *et al.*, 2010) plays an important role in the evaluation of herbicide efficacy. For most treatments, the growth reduction (%) was maximum at 4 WAT, suggesting effective weed control by all the treatments at 4 WAT (Table 3). Application of Metsulfuron-Methyl at the rates 190.5g /ha, 381g/ha and 571.4g/ha induced respective growth reductions of 60.14%, 61.86% and 70.05% at 4WAT and 55.22%, 56.08% and 58.44% respectively at 8 WAT. Similar to weed dry weight, percentage growth reduction was higher by the combined Metsulfuron-Methyl and Glisat application which may be attributed to a better synergy obtained by mixing the herbicides. The combined application of Metsulfuron-Methyl at 190.5g/ ha and Glisat @ 2.8l/ha induced a percentage growth reduction of 95.06% and 83.81% at 4 WAT and 8 WAT respectively. The combined application of 381 g/ ha Metsulfuron-Methyl and 4.3 l/ha Glisat induced higher growth reductions of 99% and 98% at 4 WAT and 8 WAT respectively. Application of Ceresate at 1.5 L/ha induced percent growth reductions of 92 and 82.8% respectively at 4 and 8 WAT.

The general increase in weed biomass and decrease in percentage weed growth reduction from 4 WAT to 8 WAT is indicative of regrowth of weeds at 8 WAT. The rate of regrowth was however different for the different treatments. Regrowth was faster in treatments with lower rates of herbicide application as well as in treatments with sole metsulfuron treatments than in the combined Metsulfuron-Methyl and Glisat treatments. For e.g. for sole Metsulfuron-Methyl application at 571.4 g/ ha, the percentage weed growth reduction reduced by 17% at 8 WAT and 36% at 16 WAT compared to the growth reduction at 4 WAT whiles for the combined application of 381g/ha Metsulfuron-Methyl and Glisat at 4.3 l/ha, the weed growth reduction was reduced by 1% and 14% at 8 and 16 WAT respectively. The lower regrowth rate in this treatment may predispose the land to erosional hazards and may also result in the

poor regrowth of the *Pueraria phaseoloides* cover crop.
Regrowth rates were also different for the different species of weeds observed (Table 4). For treatments with sole Metsulfuron-Methyl application, regrowth of grasses was completed by 8 WAT whiles for the combined Metsulfuron-Methyl and Glisat treatments as well as in Ceresate treatments, regrowth of broadleaves was faster.

Table 4. Percent herbicide efficacy of Metsulfuron-Methyl and combinations on Broadleaves and Grasses at BOPP.

Treatments	Herbicide efficacy (%)					
	4 WAT		8 WAT		16 WAT	
	Broadleaves	Grasses	Broadleaves	Grasses	Broadleaves	Grasses
Metsulfuron 0.0g/ha	0	0	0	0	0	0
Metsulfuron 190.5g/ ha	64	35	90	8	81	-7
Metsulfuron 381.0 g/ ha	66	36	87	14	76	-1
Metsulfuron 571.4 g/ha	75	41	82	26	71	11
Ceresate 1.5 l/ ha	88	100	70	95	42	76
Metsulfuron 190.5g/ ha + Glisat 2.8l/ha	93	100	76	94	46	80
Metsulfuron190.5g/ ha + Glisat 4.3l/ha	93	100	78	100	49	83
Metsulfuron 381g/ ha + Glisat 2.8l/ha	94	100	93	95	68	90
Metsulfuron 381g/ ha + Glisat 4.3l/ha	97	100	97	1.00	87	97
LSD ($P \leq 0.05$)	1.69	0.93	2.19	2.15	2.10	2.07

Herbicide efficacy in controlling weeds
Herbicide efficacy determined as the ratio of the change in weed dry weights of untreated and treated plots to the weed dry weight of untreated plot, increased with increasing herbicide dose. The effects of herbicides on grasses and broadleaves differed with the different herbicides as the efficacy of Metsulfuron-Methyl on the grasses at the site was very low (Table 4). At 4 WAT herbicide efficacy recorded by the application of sole Metsulfuron-Methyl at the different rates ranged from 35 to 41% for grasses and 64 to 75% for broadleaves whiles Ceresate application induced herbicide efficacies of 100% and 88% for grasses and broadleaves respectively. The combined application of Metsulfuron-Methyl and Glisat at all rates induced herbicide efficacies in the range of 93 and 97% for broadleaves and 100% for grasses at 4 WAT. The relatively lower efficacy of Metsulfuron-Methyl on grass species suggest that Metsulfuron-Methyl may be more effective in an area dorminated by broadleaves. Ceresate was effective in controlling most broadleaf species at the site with the exception of few species like *Commelina erecta* and *Asystacia gangetica*. Combined application of 381 g/ha Metsulfuron-Methyl and 4.3 Lt/ ha Glisat exerted a more pronounced effect in controlling all grasses and broadleaves with the exception of the woody weed *Baphia nitida*.

Percent herbicide efficacy on the different weed species also differed at 8 and 16 WAT. At 8WAT, herbicide efficacy for sole Metsulfuron-Methyl treatments range from 8 to 26% for grasses and 82 to 90% for broadleaves indicating the fast regrowth of grasses than broadleaves. Metsulfuron-Methyl was less effective in controlling the grass species than the broadleaves. The combined Metsulfuron-Methyl and

Glisat treatments induced herbicide efficacies in the range of 76 to 97% for broadleaves and 94 to 100% for grasses at 8 WAT whiles Ceresate application induced herbicide efficacies of 70 and 95% for broadleaves and grasses respectively. Regrowth of grasses was slower in the combined treatments. The findings prove that the treatments of less efficacy could cause weed to grow and recover faster or in shorter times (Mohamed *et al.*, 2010).

Table 5. Changes in oil palm vegetative parameters# at 16 WAT after treatment.

Treatment	Changes in some vegetative parameters of the young oil palm (%) at 16 WAT			
	Frond number	Plant height	Rachis length	Radius of spread
Untreated plot	8.42	7.46	8.08	5.86
Metsulfuron 190.5 g/ha	11.43	9.59	8.52	7.45
Metsulfuron 381 g/ha	12.12	11.52	11.49	7.74
Metsulfuron 571.4 g/ha	12.50	14.62	14.29	10.59
Ceresate 1.5 L/ha	16.67	19.62	18.56	14.96
Metsulfuron 190.0 g/ha + Glisat 2.8 L/ha	18.07	19.70	17.36	14.23
Metsulfuron 190.0 g/ha + Glisat 4.3 L/ha	20.00	20.65	20.14	17.00
Metsulfuron 381.0 g/ha + Glisat 2.8 L/ha	22.86	23.11	22.12	17.07
Metsulfuron 381.0 g/ha + Glisat 4.3 L/ha	27.78	23.38	22.51	22.27
LSD ($P < 0.05$)	1.66	1.22	1.14	1.17

= (Final vegetative parameter – Initial vegetative parameter)/ Initial Vegetative parameter x 100.

At 16 WAT, negative herbicide efficacies were observed by the application of sole Metsulfuron-Methyl at rates 190.5 and 381 g/ ha. Regrowth of grasses in these treatments was higher than the no herbicide treatment. Regrowth at 16 WAT also differed due to differential herbicide effects on the different weed species. For e.g. the herbicide efficacy induced by the application of sole Metsulfuron-Methyl at 571.4 g/ ha was 71 % for broadleaves and 11% for grasses whiles the efficacy for the combined application of Metsulfuron-Methyl at 190.5g/ ha and Glisat @2.8l/ha was 46% for broadleaves and 80% for grasses. For Ceresate, efficacy was 42% for broadleaves and 76% for grasses at 16 WAT. The lower regrowth rate of the treatment with combined application of Metsulfuron-Methyl at 381 g/ ha and Glisat @4.3 l/ha at 16 WAT was observed by the higher efficicacy values of 87% on broadleaves and 97% on grasses (Table 4). The application of Ceresate and combined Metsulfuron-Methyl and Glisat application were very effective in controlling grasses. Similar observations in the control of both broadleaved and grass by glyphosate at 2 and 4 WAT have been reported (Wibawa *et al.*, 2009; Mohamad *et al.*, 2010). Hussain *et al.* (2003) observed significant weed control as well as yield improvement in wheat by the application of dual purpose herbicides including Metsulfuron-Methyl. Faccini and Puricelli (2007) also observed significant weed reduction by the application of different herbicide mixtures including Metsulfuron-Methyl.

Maximum herbicide efficacy recorded at 4 WAT for some treatment in the current study do not agree withsome findings of earlier reports by Mohamed *et al.* (2010) who reported maximum weed reduction at 8 WAT. Period for maximum herbicide efficacy may vary due to herbicide type and weed species. Faccini, and Puricelli (2007), observed that weed species vary in their susceptibility to herbicides. Kataoka *et al.* (1996), found that the complete translocation of glyphosate herbicide confers remarkable efficacy on most weeds.

Metsulfuron-Methyl and Glisat as well as Ceresate were not effective in controlling the only predominant woody growth species in the area. The weed had woody stems and cuticular covering of leaves were waxy and thick. Species at the vegetative stage were usually more easily controlled by all treatments, which agrees with a study by Jordan *et al.* (1997) for other herbicides. Low control of perennial species by glyphosate has been observed in earlier studies (Bradley *et al.*, 2004).

Effect of herbicides on vegetative growth of palms

The effects of Metsulfuron-Methyl application either as a single dose or in combination with Glisat as well as Ceresate application positively enhanced vegetative development of the young oil palms at 16 WAT (Table 5). The results showed that the herbicides used at all the doses were safe to use as long as the chemicals were not sprayed directly at the plant. Generally, the measured parameters of the young oil palm were enhanced with increasing doses of Metsulfuron-Methyl application. Sole Metsulfuron-Methyl at 571.4 g ha^{-1} application rate induced high percentage changes in frond number, rachis length, plant height and radius of canopy spread which were 48%, 96%, 77% and 81% respectively higher than the untreated plot. This may be attributed to less competition for growth resources such as nutrients, light and soil moisture from the weeds, thus making these growth factors available to the young oil palm trees for growth. Ceresate application at 1.5 L ha^{-1}, induced higher vegetative development than Metsulfuron-Methyl but the combined application of Metsulfuron-Methyl and Glisat application exerted much higher effects. The combined application of Metsulfuron-Methyl at 381g ha^{-1} and Glisat at 4.3 L ha^{-1}, exerted marked effect on frond number, rachis length, plant height and radius of spread and was more than three-fold higher than the untreated plot for all observed vegetative parameters respectively. Similar improvement in growth and yield of several crop were observed by the application of other herbicides including glyphosate (Wibawa *et al.*, 2007, Agrawal and Kumar, 1998, Wibawa *et al.,* 2007, Larbi *et al.,* 2013). Results compared favourably with results of Hussain *et al.* (2003) who observed significant improvement in vegetative growth of wheat due to the application of dual purpose herbicides including Metsulfuron-Methyl.

The significant increase in growth parameters relative to the untreated plot suggests that the Metsulfuron-Methyl, Glisat and Ceresate had no adverse effects on the young oil palms as reported earlier by Turner and Gillbanks (2003).

Conclusion

This study has showed that the application of Metsulfuron-Methyl at the different doses significantly reduced the weed growth and increased the vegetative growth of the oil palm trees. However compared to Ceresate, the effect of sole Metsulfuron-Methyl in controlling weeds under the young oil palm was lower. The efficacy of the two products also differed considerably with time and weed species. Marked effects on weed control were obtained by the combined application of 381 g/ha Metsulfuron-Methyl and 4.3 l/ha Glisat. However this treatment combination rendered the land bare for a longer period of time with difficult regrowth of cover crops. Therefore a combined application of Metsulfuron-Methyl at 190.5 g/ha and Glisat 2.8 L/ha is recommended in controlling both broadleaves and grasses under oil palm plantations. Metsulfuron-Methyl and Ceresate had no adverse effect on the oil palm and significantly improved vegetative parameters by reducing competition with weeds for nutrients and other growth resources. The use of Metsulfuron-Methyl as a sole application may be more effective in an area dorminated by broadleaves than by grass species.

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