

Phytotoxic Activity of Oil Palm Frond Mulch in Combination with Selected Pre-Emergence Herbicide

(Aktiviti Fitotoksik Sungkupan Pelepah Kelapa Sawit dalam Gabungan dengan Herbisid Pracambah Terpilih)

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ABSTRACT

*The combination of mulch and herbicide is a promising method for weed control which could reduce the frequency of hand weeding. This study was conducted to evaluate the phytotoxic effects of *Elaeis guineensis* var. tenera (oil palm) frond (OPF) mulch in combination with several pre emergence herbicides on the inhibition of goosegrass (*Eleusine indica* (L.) Gaertn), slender cyperus (*Cyperus distans* L.f.) and coat buttons (*Tridax procumbens* (L.)) under greenhouse conditions. Three rates of dinoterb, oxyfluorfen, and isoxaflutole were respectively, applied with or without OPF mulch at 3.5 t ha⁻¹. The results showed that the weed inhibition provided by the dinoterb-treated OPF mulch (60 to 100%) was greater than dinoterb (0 to 50%) or OPF mulch (0 to 60%) applied alone across all the application rates and bioassay species. The oxyfluorfen-treated OPF mulch also gave greater inhibition (70 to 90%) of *T. procumbens* than those provided by oxyfluorfen (20 to 40%) or the OPF mulch alone (55 to 60%). However, an increase in inhibition of *C. distans* and *E. indica* was only evident at a low rate of oxyfluorfen when combined the OPF mulch. Weed inhibition was noted with increasing rates of isoxaflutole alone but the isoxaflutole-treated OPF mulch did not lead to further inhibition of weeds except for *T. procumbens*. These results suggest that the phytotoxicity of OPF mulch in combination with herbicides are dependent on weed species, herbicides, and application rates, with dinoterb being the most compatible with OPF mulch when combined.*

Keywords: *Elaeis guineensis* var. tenera; oil palm frond; rachis; residue mulch; seedling emergence; seedling growth

ABSTRAK

*Gabungan antara sungkupan dan herbisid adalah kaedah yang berpotensi untuk mengawal rumpai kerana ia boleh mengurangkan kekerapan merumpai menggunakan tangan. Kajian ini dijalankan untuk menilai kesan fitotoksik sungkupan pelepah *Elaeis guineensis* var. tenera (kelapa sawit), OPF dengan gabungan beberapa herbisid pracambah ke atas perencatan rumput sambau (*Eleusine indica* (L.) Gaertn), slender cyperus (*Cyperus distans* L.f.) dan rumpai kancing baju (*Tridax procumbens* (L.)) di bawah keadaan rumah hijau. Tiga kadar dinoterb, oksifluorfen dan isoksaflutol, masing-masing diaplikasikan dengan atau tanpa sungkupan OPF pada 3.5 t ha⁻¹. Keputusan menunjukkan bahawa perencatan rumpai yang diberi sungkupan OPF terawat dinoterb (60 hingga 100%) lebih besar berbanding dinoterb (0 hingga 50%) atau sungkupan OPF (0 hingga 60%) sahaja untuk semua kadar aplikasi dan spesies bioasai. Sungkupan OPF terawat oksifluorfen juga memberikan perencatan yang besar (70 hingga 90%) ke atas *T. procumbens* berbanding oksifluorfen (20 hingga 40%) atau sungkupan OPF sahaja (55 hingga 60%). Walau bagaimanapun, peningkatan perencatan ke atas *C. distans* dan *E. indica* hanya ketara pada kadar oksifluorfen yang rendah apabila digabungkan dengan sungkupan OPF. Perencatan rumpai dapat dilihat dengan peningkatan kadar isoksaflutol sahaja tetapi sungkupan OPF terawat isoksaflutol tidak membawa kepada perencatan rumpai kecuali untuk *T. procumbens*. Keputusan ini mencadangkan bahawa kefitotoksikan sungkupan OPF dengan gabungan herbisid bergantung kepada spesies rumpai, herbisid, dan kadar aplikasi, dengan dinoterb paling sesuai digabungkan dengan sungkupan OPF.*

Kata kunci: *Elaeis guineensis* var. tenera; kemunculan anak benih; pelepah kelapa sawit; pertumbuhan anak benih; rakis; sisa sungkupan

INTRODUCTION

Organic mulch is one of the most common method for weed control in landscape planting beds. It can reduce water loses through evapotranspiration and conserve moisture

as well as nutrient, reduce soil degradation, nourish rhizosphere biota, and reduce farm inputs and greenhouse gases emissions (Malhi & Lemke 2007; Sharma et al. 2011). Typically, organic mulch is derived from plant

materials, such as hardwood and softwood bark, rice hulls, lawn clippings, pine needles, sawdust, straw, and wood chips (Somireddy 2012). Oil palm (*Elaeis guineensis* var. *tenera*) fronds (OPFs) are commonly used for mulching in oil palm cultivation (Khalid et al. 1999). Pruned OPFs are available all year, and whole fronds are placed around the base of oil palm trees to improve fertility and reduce soil erosion (Dilipkumar et al. 2017a; Moraidi et al. 2012). Dilipkumar et al. (2015) showed that OPF mulch is better than the residual mulch of pineapple and coconut in inhibiting goosegrass (*Elaeusine indica* (L.) Gaertn) emergence and growth. Moreover, OPF rachis extracts prevent *E. indica* seed germination at concentrations as low as 1.0% (w/v) (Chuah & Lim 2015). The OPF mulch containing 21% lignin and 33% hemicellulose (Lai et al. 2016) as well as have high level of allelochemicals such as flavonoids which act additively or synergistically with preemergence herbicide, imazethapyr (Dilipkumar et al. 2015, 2019; Muhammad Amirul et al. 2019).

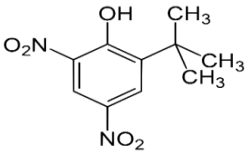
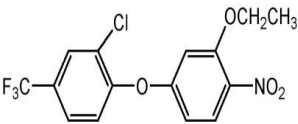
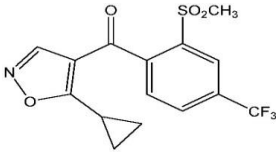
Preemergence herbicide is utilized as a part of weed control strategy in nursery and landscapes. There are few preemergence herbicides used widely in landscapes, namely pendimethalin, prodiamine, oxyfluorfen, s-metolachlor, dichlobenil, isoxaben, and indaziflam (Senseman 2007). However, no single herbicide can control a wide range of weeds. Prepackaged blends of herbicides or tank-blending individual broadleaf herbicide

with graminicide are a typical practice to accomplish wide range weed control (Altland et al. 2003; Judge et al. 2003). For instance, new granular herbicide premixes, such as oxadiazon plus prodiamine and oxyfluorfen plus oxadiazon, are becoming increasingly popular for their broad spectrum weed control in nurseries and landscapes (Somireddy 2012).

Many factors could affect performance of preemergence herbicide. Adsorption, leaching, and volatilization are the physical processes that occur to preemergence herbicides in the soil. Herbicide losses are regularly higher for fluid formulation as compared to granular formulation (Mahnken et al. 1992). For example, emulsifiable concentrations can make the herbicides more inclined to losses by runoff or leaching (Gorski 1993). Herbicides that quickly discharge active ingredients can likewise reduce the time of weed control compared to slow-release formulations (Sopena et al. 2009). These worries specified demonstrate a reasonable requirement for new herbicide application strategies that decrease off target herbicide movement.

In the landscape management and maintenance, applying herbicides above or below the mulch and incorporated in the mulch, commonly provides long-term and broad-spectrum weed control (Case & Mathers 2006; Marble 2015). Nevertheless, herbicides behave differently when applied to different organic materials (Case et al.

TABLE 1. Chemical and physical properties of dinoterb, oxyfluorfen and isoxaflutole

Active ingredient	Dinoterb	Oxyfluorfen	Isoxaflutole
Chemical structure			
Molecular weight	257.2	361.7	359.3
Chemical family	Dinitrophenol (Phenol)	Diphenylether	Isoxazole
WSSA group	24	14	27
Mode of action	Uncoupler of oxidative phosphorylation (Membrane disruption)	Protoporphyrinogen oxidase (PPO) inhibitor	Bleaching (4- hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitor)
Water solubility (mg/L)	4.5 at pH 5, 20 °C	1.16 x 10 ⁻¹ at 25 °C	6.2 at pH 5.5 and 20 °C
K _{oc} (ml/g)	98	100,000	134
Ionic properties	Weak acid	Non ionic	Non ionic

(Martins & Mermoud 1998; Plimmer et al. 2002; Shaner 2014; Taylor et al. 2000)

2002; Marble 2015; Mathers 2003; Mathers & Case 2010). For instance, interactions between organic mulch and herbicides have produced mixed results ranging from no interaction (Chen et al. 2013), antagonism (Chauhan & Abugho 2012), or synergism (Case & Mathers 2006; Mathers & Case 2010) depending on the placement, type, and rate of herbicides and plant residues used. Chen et al. (2013) reported that the application of EPTC above pine mulch provided 70% control of yellow nutsedge (*Cyperus esculentus* L.), however, when EPTC applied beneath the mulch exhibited 85% reduction in *C. esculentus*. Conversely, flumioxazin-treated hardwood mulch exhibited greater efficacy on weed and reduce phytotoxicity on crop compared to those treated with mulch or flumioxazin alone (Case & Mathers 2006). According to Chauhan and Abugho (2012), pendimethalin application at 1 kg ha⁻¹ resulted in lower barnyard grass (*Echinochloa crus-galli* (L.) P. Beauv.) control in the presence of 6 t ha⁻¹ rice residue relative to the same application in the absence of residue. Information is scarce with regard to the phytotoxic effects of OPF mulch combined with dinoterb, oxyfluorfen, or isoxaflutole for weed inhibition in landscapes and nurseries. Pre-emergence herbicides are studied in the current research because of their distinct chemical and physical properties (Table 1) that are thought to change their inhibitory effect when combined with residual OPF mulch. The objectives of this study were: to evaluate the effects of residual OPF mulch applied alone on the seedling emergence and growth of selected weeds in landscapes and nurseries; goosegrass (*Eleusine indica* (L.) Gaertn), slender cyperus (*Cyperus distans* L.f.) and coat buttons [*Tridax procumbens* (L.)]; and to assess the inhibitory effects of dinoterb, oxyfluorfen, and isoxaflutole on several common weeds following three herbicide rates applied with or without residual OPF mulch.

MATERIALS AND METHODS

PLANT MATERIALS

Seeds of common weed species found in landscapes, including goosegrass (*Eleusine indica* (L.) Gaertn), slender cyperus (*Cyperus distans* L.f.) and coat buttons (*Tridax procumbens* (L.)) represented grassy weed, sedge, and broadleaf weed, respectively, were collected from Bukit Kor, Marang, Terengganu, Malaysia (5°22'N, 103°18' E). *Eleusine indica* seeds were scarified with sandpaper to encourage germination (Ismail et al. 2002). Seeds of each species were soaked in 0.2% potassium nitrate solution for 24 h to break dormancy prior being used. A preliminary viability test was conducted, and the results confirmed that germination rates > 90%. Fresh OPFs were collected from 35-year-old trees near MARDI, Seberang Prai, Pulau Pinang, Malaysia (5°54'N, 100°47'E). OPFs were initially cut into small pieces with lengths ranging from 6 cm to 10 cm using a chopper machine (DISK MILL FFC-23, Shandong JimoHairong Machinery Co. Ltd.) and then sun-dried in a greenhouse for a month. After

complete drying, the OPF pieces were ground to powder using the same mill (< 2 mm particle size) and stored at 4 °C prior to use.

GREENHOUSE EXPERIMENTS

Experiments were conducted in the greenhouse with 12 h photoperiods. Temperature and light intensities ranged from 29 to 32°C and 800 to 1200 $\mu\text{Em}^{-2}\text{s}^{-1}$, respectively. Greenhouse was located at the School of Food Science and Technology, Universiti Malaysia Terengganu, Terengganu, Malaysia (5.24°N, 103.05°E).

A total of 150 g of sandy clay soil (44% clay, 10% silt, and 46% sand; pH 4.3; 1.7% organic matter; 0.5% nitrogen (N); 1.7 mg/kg phosphorus (P); 102.1 mg/kg potassium (K) mg/kg; and 2.2 meq/100g CEC) was mixed with 0.22 g of dry chicken dung (1.5% N, 0.4% P, and 0.8% potassium) and placed in a paper cup (7 cm diameter \times 9 cm height) with six holes at the bottom for drainage. Each cup was placed in a 50 \times 100 cm tray, and water was applied to the tray to allow the capillary uptake of water from the bottom of the cup. Water was removed from the tray when the soil surface appeared moist. Ten seeds of *E. indica*, *C. distans*, or *T. procumbens* were sown on the soil surface in the cups and then placed in the greenhouse. Analytical standard of dinoterb, oxyfluorfen, and isoxaflutole were used to treat the OPF mulch powder to eliminate confounding factor due to adjuvant of commercial grade of herbicide. A preliminary dose-response test was carried out to determine three herbicide rates that resulted in 0 to 90 % of weed inhibition. Dinoterb was applied at 0, 0.38, 1.5, and 6 g a.i ha⁻¹; oxyfluorfen at 0, 0.12, 0.49, and 1.95 g a.i ha⁻¹; and isoxaflutole at 0, 0.16, 0.33, and 0.65 g a.i ha⁻¹ with or without OPF mulch at 3.5 t ha⁻¹.

The OPF mulch preparation and application rate were followed as described by Dilipkumar et al. (2015). Each herbicide (active ingredient) was dissolved in 5 mL of acetone and pipetted into a 9 cm Petri dish containing 1.56 g of sieved soil (2 mm) or 1.56 g of residual OPF powders at room temperature. An additional 4 and 8 mL of acetone were poured into the soil and OPF mulch powder, respectively, to create a uniform distribution of each herbicide. Each Petri dish was sealed and gently shaken to allow the thorough incorporation of the solution into the soil or OPF mulch powder. The Petri dishes were then placed in a fume hood for 24 h prior to application into the paper cup. Irrigation with 10 mL of water applied to the top of each cup was performed daily. At three weeks after treatment (WAT), the pH of the soil treated with OPF alone was measured, seedling emergence rate (SER) was recorded on the basis of the number of seeds with emerged shoots, and above-ground plant tissue was harvested and oven dried at 60 °C for two weeks to obtain the shoot dry weight (SDW). The seedlings were considered emerged when the plumule lengths were > 2 mm. Cups with seeded but untreated soil (without herbicide and OPF mulch) served as controls. The data were expressed as percentages of their respective controls.

$$\text{SER} = (\text{ET}/\text{EC}) \times 100\% \quad (1)$$

$$\text{SDW} = (\text{SDT}/\text{SDC}) \times 100\% \quad (2)$$

where ET is number of seeds with emerged shoots in treatment (mulch alone, herbicide alone or herbicide-treated mulch); EC is number of seeds with emerged shoots in untreated soil (without OPF mulch and herbicide); SDT is SDW in treatment; and SDC is SDW in untreated soil.

EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

The experiment was arranged in a completely randomized design with three replications and then repeated twice in time. Weed emergence and shoot biomass percentages of each species were checked for homogeneity of variance. In some circumstances, data were transformed to improve variance homogeneity. For example, an arcsine square root transformation was performed on the percent data for *E. indica* seedling emergence treated with isoxaflutole. Square root ($x + 1$) transformation was conducted for the seedling biomass of the *T. procumbens* treated with dinoterb. The

data were then subjected to a two-way ANOVA where factor 1 is herbicide rate (3 different rates) while factor 2 is presence of OPF mulch (with or without). Data were combined because of no effect of time. The means were compared using Tukey's honestly significant difference test at a 5% significance level.

RESULTS AND DISCUSSION

The application of oil palm frond (OPF) mulch alone at 3.5 t ha^{-1} inhibited the *E. indica* and *T. procumbens* seedling emergence by 20 and 58%, respectively, and had no significant effect on *C. distans* (Table 2), implying that the efficacy of residual OPF powder on inhibiting seedling emergence is species dependent with *C. distans* being the least sensitive and *T. procumbens* the most sensitive. However, shoot growth of the weeds was inhibited approximately by 60% regardless of any weed species (Table 2). In general, there was a significant interaction between application of herbicide and the presence of mulch on weed seedling emergence and weed growth inhibition except for *T. procumbens* treated with oxyfluorfen (Figures 1, 2 & 3).

TABLE 2. Inhibitory effect of oil palm frond (OPF) powder alone at 3.5 t ha^{-1} on *Eleusine indica*, *Cyperus distans* and *Tridax procumbens* three weeks after treatment

Weed species	Seedling emergence	Shoot dry weight
	(% of control)	
<i>Eleusine indica</i>	20	60
<i>Cyperus distans</i>	99	60
<i>Tridax procumbens</i>	58	59

*Untreated soil (without herbicide and OPF) is served as control

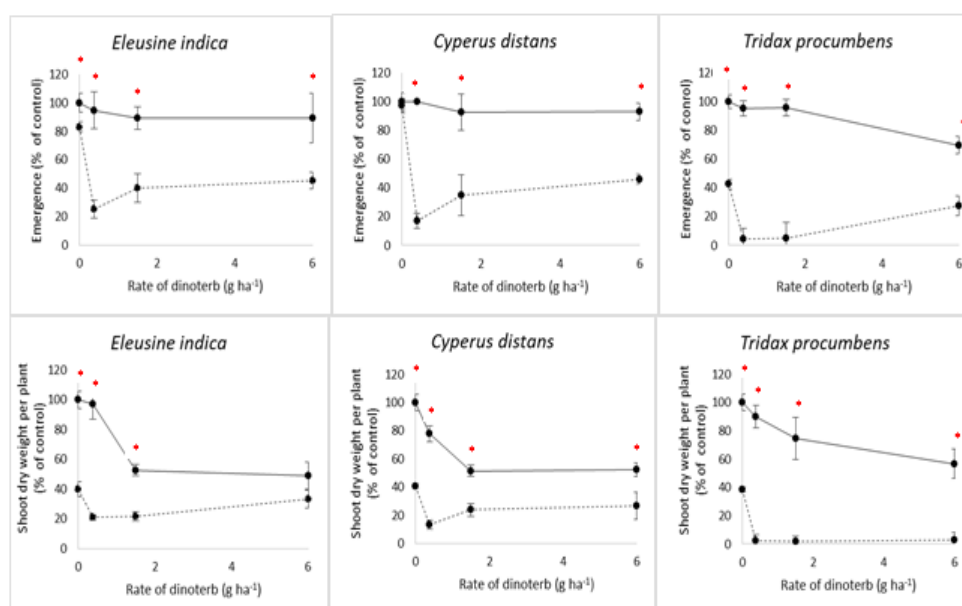


FIGURE 1. Inhibitory effect of dinoterb (—) and dinoterb-treated oil palm frond residue mulch (- -) on seedling emergence and growth of *Eleusine indica*, *Cyperus distans* and *Tridax procumbens* three weeks after treatment. The untreated soil (without herbicide and OPF mulch) is served as control.

* denotes significant difference between herbicide alone and herbicide + mulch within the same herbicide rate at 5% of significant level

PHYTOTOXICITY OF OPF MULCH COMBINED WITH
DINOTERB

Dinoterb alone failed to effectively inhibit seedling emergence of each bioassay species irrespective of any application rate (Figure 1). In contrast, the weed growth was inhibited by 5 to 50% with increasing rates of dinoterb applied alone, indicating that dinoterb acts a shoot inhibitor rather than germination inhibitor. Interestingly, the inhibition of weed emergence and growth were significantly increased by 60 to 100% by the dinoterb-treated OPF, but the herbicide rates greater than 0.38 g ha^{-1} appeared to be unnecessary for adequate control of weed species when combined with the OPF mulch. Weak acid herbicides, such as dinoterb, tended to absorb soil particles because its pKa (4.8) value (Escher & Schwarzenbach 2000) is close to the soil pH value (4.3) of the present study, thereby leading to low inhibition of weed emergence when applied alone. It has been shown that wheat (*Triticum aestivum* L.) straw temporarily increased the soil pH (Schmitz et al. 2001). Likewise, the OPF mulch could increase the soil pH from 4.3 to 6.0 in the present study. Dinoterb has a predominantly negative charge (Kah & Brown 2006) when the soil pH is close to 7, thus leading to free dinoterb molecules available for root uptake with greater inhibition of weed. Nevertheless, the leaching potential of dinoterb is likely to be high due to its low Koc of 98 mLg^{-1} (Martins & Mermoud 1998) with a water solubility of 4.5 mgL^{-1} (Shaner 2014) but dinoterb leaching could be reduced because the OPF mulch may act as a slow release carrier of dinoterb as reported by Dilipkumar et al. (2017b) when the OFF mulch was

combined with weak acid herbicide like imazethapyr.

PHYTOTOXICITY OF OPF MULCH COMBINED WITH
OXYFLUORFEN

Seedling emergence of weeds was inhibited with increasing rates of oxyfluorfen applied alone (Figure 2). Oxyfluorfen at the lowest rate of 0.12 g ha^{-1} resulted in approximately 60% inhibition of weed growth. However, the suppression of weed growth by oxyfluorfen was significantly increased to 90% at 0.12 g ha^{-1} with the presence of OPF mulch. Oxyfluorfen has high Koc of $100,000 \text{ mgL}^{-1}$ and low water solubility of 0.12 mgL^{-1} (Alister et al. 2009; Shaner 2014) which cause the herbicide is strongly adsorbed by soil organic matter. As a result, few oxyfluorfen molecules are free for root uptake, thereby leading to moderate inhibition of weed growth when applied alone at 0.12 g ha^{-1} . However, the OPF mulch may act as a slow release carrier of oxyfluorfen at 0.12 g ha^{-1} and caused further significant increase in weed growth inhibition. *Tridax procumbens* was more tolerant than *E. indica* and *C. distans* when treated with oxyfluorfen alone, suggesting that herbicidal activity of oxyfluorfen is selective. Interestingly, the herbicide selectivity on *T. procumbens* could be overcome after combined with the OPF mulch. However, there was no benefit of increasing the rate of oxyfluorfen over 0.12 g ha^{-1} in combination with the OPF mulch on seedling emergence and growth of all tested weeds. This result indicates that compatibility of the OPF mulch with oxyfluorfen is influenced by herbicide rate and bioassay species.

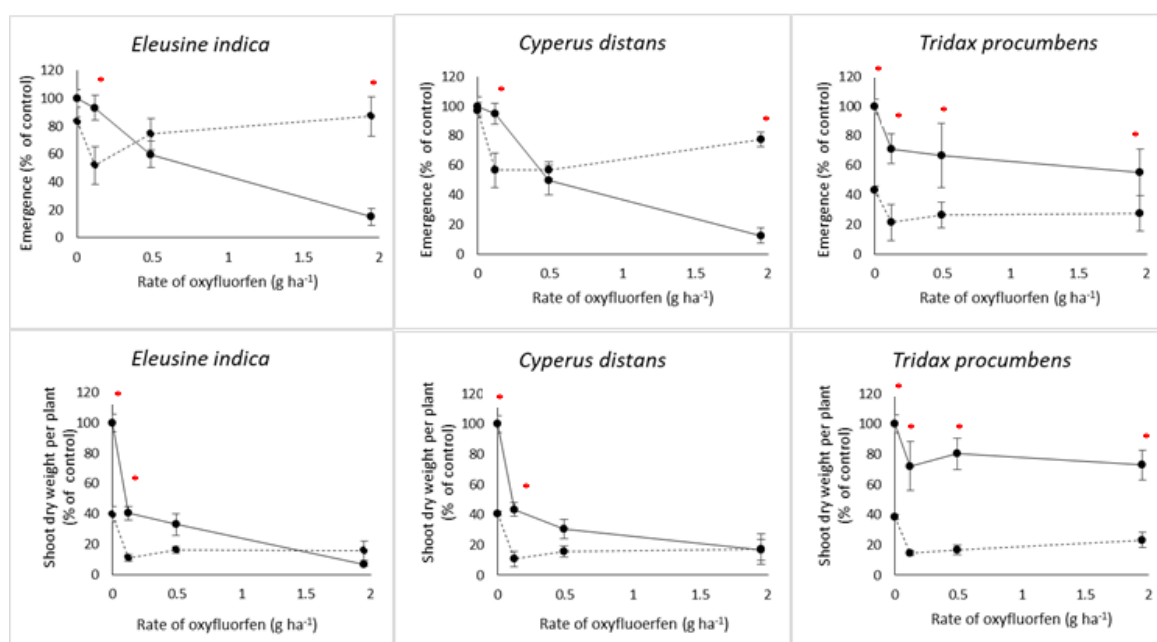


FIGURE 2. Inhibitory effect of oxyfluorfen (—) and oxyfluorfen-treated oil palm frond residue mulch (- -) on seedling emergence and growth of *Eleusine indica*, *Cyperus distans* and *Tridax procumbens* three weeks after treatment. The untreated soil (without herbicide and OPF mulch) is served as control. * denotes significant difference between herbicide alone and herbicide + mulch within the same herbicide rate at 5% of significant level

PHYTOTOXICITY OF OPF MULCH COMBINED WITH
ISOXAFLUTOLE

Weed seedling emergence was inhibited with increasing rates of isoxaflutole applied alone (Figure 3). Isoxaflutole applied alone at 0.33 and 0.65 g ha⁻¹ significantly reduced the seedling emergence of *C. distans* by up to 90%, but the inhibition of emergence was reduced to 40% when subjected to the isoxaflutole-treated OPF. In contrast, significant reduction in the emergence of *T. procumbens* was noted when treated with the pretreated OPF as compared to isoxaflutole alone across all application rates (Figure 3). Weed shoot growth was inhibited with increased rates of isoxaflutole alone. Interestingly, the isoxaflutole-treated OPF provided greater reduction of *T.*

procumbens growth, whereas there were no significant differences on *E. indica* and *C. distans* which were almost similar to isoxaflutole alone at the rate of isoxaflutole over 0.16 g ha⁻¹. There was no benefit of increasing the rate of isoxaflutole over 0.16 g ha⁻¹ in combination with the OPF mulch on seedling emergence and growth of weeds. In addition, these results also imply that the OPF mulch is not a good carrier for slow release of isoxaflutole probably due to its lack of stability and natural hydrolysis to its diketnitrile (DKN) derivative (Pallet et al. 2001), which tends to leach more than isoxaflutole does (Alletto et al. 2012) as a result of a low Koc value (17 gmL⁻¹) and the high value of water solubility (326 gmL⁻¹).

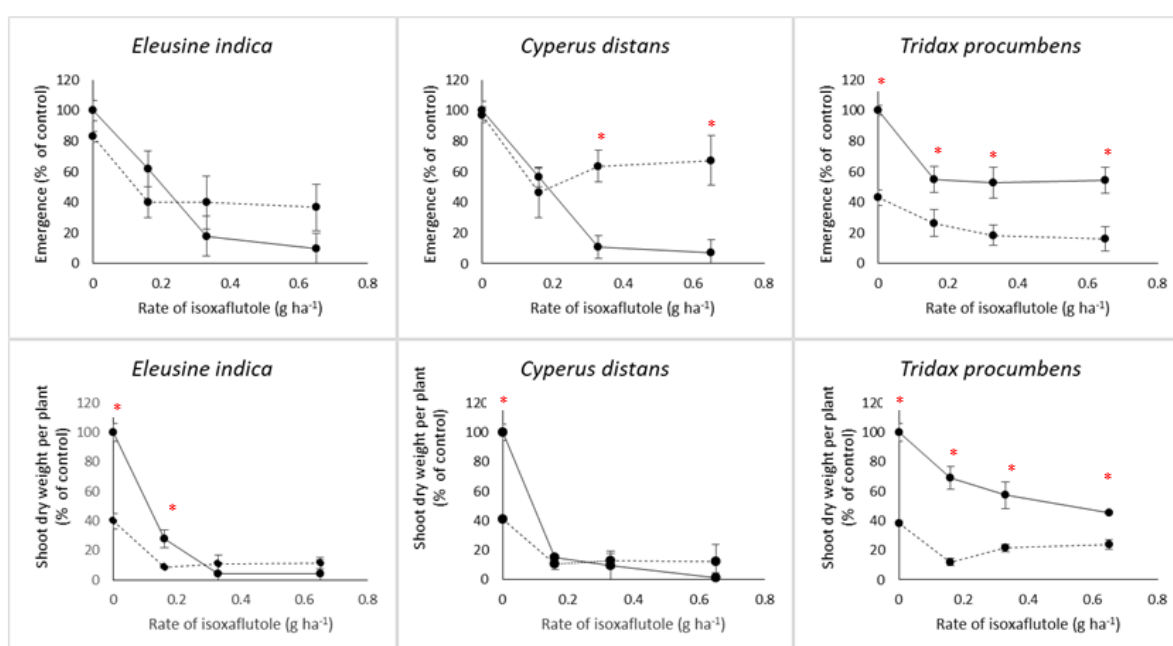


FIGURE 3. Inhibitory effect of isoxaflutole (—) and isoxaflutole-treated oil palm frond residue mulch (- -) on seedling emergence and growth of *Eleusine indica*, *Cyperus distans* and *Tridax procumbens* three weeks after treatment. The untreated soil (without herbicide and OPF mulch) is served as control. (* denotes significant difference between herbicide alone and herbicide + mulch within the same herbicide rate at 5% of significant level)

CONCLUSION

In summary, the emergence and seedling growth of weeds were suppressed greatly when subjected to OPF mulch treated with dinoterb regardless of the application rate and bioassay species, suggesting high compatibility between dinoterb and the OPF mulch. Interactions between OPF mulch and oxyfluorfen or isoxaflutole were rate and species dependent. Differential interactions between

preemergence herbicides and OPF mulch are most likely related to herbicide selectivity to weed, the chemical and physical properties of herbicides.

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