DOI : 10.5958/0974-0112.2019.00021.5

Indian J. Hort. 76(1), March 2019: 148-154

Effects of imazethapyr treated oil palm frond residue mulch on weed control and ornamental plant quality in nurseries

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ABSTRACT

A combination of oil palm frond (OPF) mulch and imazethapyr has been shown to provide good weed control in crop plantations, but information on its potential use for weed control in nurseries is limited. This study aims to evaluate the effect of imazethapyr in combination with OPF mulch on the inhibition of goosegrass, slender cyperus, coat buttons and phytotoxicty on ornamental plants under glasshouse conditions. Three suboptimal rates of imazethapyr, representing low, medium and high rates, are applied alone or used to treat 3.5 t ha^{-1} OPF residue powder (< 2mm). The low rate of imazethapyr at 10 g a.i. ha^{-1} and the OPF mulch alone inhibit seedling growth of goosegrass, slender cyperus and coat buttons by 40%–60%. The OPF mulch treated with imazethapyr at this rate acts synergistically and provides 80%–95% inhibition ofweed growth. However, increasing the rate of imazethapyr over 10 g a.i. ha^{-1} does not further improve weed inhibition, and results in antagonism on goosegrass and slender cyperus emergence. A subsequent experiment with the low rate of imazethapyr incorporated with OPF mulch causes moderate phytotoxicity on Chinese aloe and coral swirl, but minimal or no injury was observed for jasmine, cactus, puding and euodia at 4–12 weeks after treatment. Results suggest that incorporation of imazethapyr at 10 g a.i. ha^{-1} with OPF mulch can effectively control goosegrass, slender cyperus and coat buttons without injuring jasmine, cactus, puding and euodia.

Keywords: imazethapyr, oil palm frond residue mulch, weed control, ornamental plant.

INTRODUCTION

In horticulture, weed competition and interference can result in ornamental plants with low vigour, reduced leaf size and few flowers (Adams,1). The plants with reduced growth result in low prices, and some long-term crops may need to grow an extra year to reach sellable size. Moreover, consumers prefer weed-free container-grown plants over weedy container grown plants (Simpson *et al.*, 27). Weeds and ornamental plants differ in their competitive capability for limited resources. Weeds often have the advantage over agronomic or horticultural plants owing to their genetic traits for competition and reproduction (Somireddy, 28). Some crop plants are extremely sensitive to weed competition, and weeds can reduce plant growth significantly in container and field nursery productions. Some weeds do not reduce the growth of nursery crops; however, a container-grown plant with weeds present is a less marketable product than a weed-free product (Norcini and Stamps, 24). Furthermore, weeds reduce the aesthetic value of landscapes.

Hence, weed control is essential for nursery growers and landscape professionals. Applying herbicides 3–5 times per growing season is often essential in container nurseries (Gilliam *et al.*, 14), and it is usually done twice a year in field nurseries and landscapes with supplemental applications of hand-weeding. Moreover, landscape weed control programmes can succeed by using organic mulch in combination with selected herbicides. Depending on the type of mulch that is used, weed growth can be reduced by means of light exclusion, reduction of available air and water in the seedbed, allelopathic chemical leaching or the creation of a physical barrier (Chalker–Scott, 7). Benefits from organic mulches have been well established, and several mulch products are available for landscape use. In many cases, pre-applied herbicides are used in combination with different mulch materials to provide increased durations of weed control and suppress a broader spectrum of weed species (Mathers and Case, 22; Marble, 21).

The present study used oil palm fronds (OPF) as organic mulch because of its supply availability throughout the year i*n oil palm cultivation* (Khalid *et al.*, 17). In addition, Chuah and Lim (9) found that the rachis extract of OPF mulch provided complete inhibition of goosegrass germination at a concentration of as low as 1.0% (w/v). Imazethapyr,

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an imidazolinone herbicide, is selected in the current study because it does not readily leach depending on soil pH under field conditions (McDowell *et al*., 23) and is relatively persistent in soil with half-lives ranging from 30–150 days (Curran *et al*., 10). At soil pH values greater than 6, these compounds primarily exist as negative ions and are weakly sorbed (Mangels, 20). As the soil pH decreases and the compounds become less ionic, greater amounts of imazethapyr are sorbed (Loux *et al*., 19). Imidazolinone herbicides have become widely used because of their low application rates, lowereffects on environmental and selectivity in a wide range of cropping systems (Babu *et al.,*3). Research on the potential of imazethapyr for weed control in nurseries is limited, with imazethapyr being limited to use in soybean, several other leguminous crops (Barkani *et al*.,4) and oil palm (Dilipkumar *et al.,*12). According to Vencill (29), imazethapyr generally absorbs rapidly into foliage, where interference occurs in DNA synthesis and cell growth is affected owing to the inhibition of acetolactate synthase. The injury symptoms usually appear after 1–2 weeks or more. Meristematic areas becomechlorotic, followed by a slow general foliar chlorosis, and necrosis results from events occurring in response to acetolactate synthase (ALS) inhibition.

The imazethapyr-treated OPF mulch has been demonstrated as new potential weed management strategy in controlling common weeds of *Mikania micrantha* Kunth, *Asystasia gangetica* (L.) T. Anderson*, Phyllanthus amarus* Schumach and Thonn and *Panicum* sp. and *Echinochloa colona* (L.) Link in coconut plantations (Dilipkumar *et al*. 12). However, no attempt has been carried out to examine the use of imazethapyr-treated OPF mulch for weed control in nurseries. Determining synergism or antagonism of imazethapyr-treated OPF mulch for weed control is much-needed information for assessing its potential use in the landscape industry. In addition, the phytotoxicity of imazethapyr-treated OPF mulch on ornamental plants remain unknown, but numerous studies showed that phytotoxic effects of herbicide-treated on the ornamental plants are species dependent (Case and Mathers 5). The objectives of this study are to evaluate effects of imazethapyr-treated OPF mulch on inhibition of selected weeds and quality of six selected ornamental plant species in nurseries.

MATERIALS AND METHODS

Glasshouse experiments were conducted during 2018 at the School of Food Science and Technology, Universiti Malaysia Terengganu, Terengganu, Malaysia (5.24°N, 103.05°E) with temperature and light intensity ranging from 29°C–32°C and 800–1,200 $\mu Em^{-2}s^{-1}$, respectively.

Analytical standard grade of imazethapyr (99.9% purity) (Table 1) was purchased from PESTANAL®, Sigma–Aldrich. Seeds of three common weed species found in landscapes including goosegrass (*Eleusine indica*), slender cyperus (*Cyperus distans*) and coat buttons (*Tridax procumbens*) which represent grassy weed, sedge and broadleaf weed, respectively, were collected from Bukit Kor, Terengganu, Malaysia (5° 22'N, 103° 18'E). *Eleusine indica* seeds were scarified with sand papers. Seeds of each bioassay species were soaked in 0.2% potassium nitrate solution for 24 h to break dormancy before being used. A preliminary viability test was conducted and confirmed that germination rate of the seeds had more than 90%. Fresh OPF (*Elaesis guneensis* var. *tanera*) were collected from Mardi Seberang Perai Pulau Pinang, Malaysia (5° 54'N, 100° 47'E). The fronds were harvested from 35-year old oil palm trees; they were cut into small pieces with 6–10 cm length using a chopper machine (DISK MILL FFC-23, Shandong Jimo Hairong Machinery Co. Ltd) and dried under direct sunlight in the glasshouse for one month. Once completely dried, the OPF residue powders (<2 mm) were stored in a chiller (4 °C) prior to use. Ornamental plants (Table 2) were purchased from Semaian Mesra Nursery Sdn. Bhd.

A total of 150 g (44% clay, 10% silt and 46% sand, pH 4.3, 1.7% organic matter, 0.5% nitrogen, 1.7 mg/kg phosphorus, 102.1 mg/kg potassium mg/kg and 2.2 meq/100g cation exchange capacity) sandy clay soil was mixed with 0.22 g chicken dung and filled in a paper cup (7 cm diameter × 9 cm height) with six holes at the bottom. The cup was then placed in a 50 × 100 cm tray, and water was applied from the bottom of the cup until moist condition was achieved. Ten

Table 1. Physico-chemical properties of imazethapyr (Vencill, 30 and Gillespie *et al*., 13).

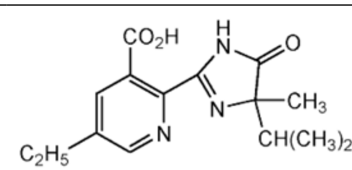
Chemical structure	
Molecular weight	289.33
Chemical family	Imidazolinone
Water solubility (mg/L)	1400 at pH 7 and 25°C
Koc (mL/g)	97-283
Ionic property	Weak acid
Mode of action	Inhibits acetolactate synthase (ALS)

Table 2. List of ornamental plants and visual rating scheme (adapted from Chen *et al.*, 8).

Ornamental plant species	Family	Flowering	Leaves	Colourful (Leaves)	Visual rating based on part of plant (1-10)
Wrightia antidysenterica (coral swirl)	Apocynaceae	Yes	Yes	No	Size (height) (3m), foliage greenness (3m), fullness (2m), flowering (2m)
Jasminum grandiflorum (jasmine)	Oleaceae	Yes	Yes	No	Size (height) (3m), foliage greenness (3m), fullness (2m), flowering (2m)
Aloe humilis (cactus)	Xanthorrhoeaceae	No	No	No	Size (height) (3m), leaves greenness (3m), fullness (2m), flowering (2m)
Aloe vera (chinese aloe)	Asphodelaceae	No	No	No	Size (height) (3m), leaves greenness (4m), fullness (3m)
Codiaeum variegatum (puding)	Euphorbiaceae	No	Yes	Yes	Size (height) (4m), foliage color (4m), fullness (2m)
Euodia suaveolens (euodia)	Rutaceae	No	Yes	No	Size (height) (4m), foliage greenness (4m), fullness (2m)

seeds of goosegrass were sown on the soil surface for each cup under glasshouse conditions. The same procedure was repeated for slender cyperus and coat buttons. Imazethapyr (Table 1) was used to treat OPF residue mulch powders. The recommended rate of imazethapyr is 240 g ai ha^{-1} (Dilipkumar *et al.*, 12). Imazethapyr was examined at three suboptimal rates which are 10, 41 and 166 g ai ha^{-1} in combination with or without OPF residue mulch powder at 3.5 t ha^{-1}. Herbicide was dissolved in acetone and pipetted into 9 cm diameter Petri dish containing of 1.56 g sieved soil (2 mm) or 1.56 g OPF residue powders at room temperature. An additional 4 and 8 ml acetone were poured into the soil or OPF residue powders to create a more uniform of distribution of each herbicide. Each Petri dish was sealed and gently shaken to allow thorough incorporation of the solution into the soil or OPF residue powders and placed in a fume hood for 24 h. One day after seed sowing, the herbicide-treated soil, OPF residue powders and herbicide-treated OPF residue powders were placed on the soil surface of each paper cup containing 150 g soil and irrigated with 10 mL of water from the top of cup daily to ensure seed germination. Three weeks after treatment (WAT), seedling emergence rate (SER) was recorded based on number of seeds with emerged shoots, and above ground plant tissue was harvested and oven-dried at 60 °C for two weeks to obtain shoot dry weight (SDW). Seedlings were considered emerged when the plumule lengths were > 2 mm. The untreated soil served as control. The data were expressed as percentages of their respective controls as follows:

$$SER = (ET/EC) \mid \times 100\% \quad (1)$$

$$SDW = (SDT/SDC) \mid \times 100\% \quad (2)$$

where ET is the number of seeds with emerged shoots in treatment, EC is the number of seeds with emerged shoots in untreated soil, SDT is SDW in treatment and SDC is SDW in untreated soil. The experiment was arranged in a completely randomised design with three replications and repeated twice.

Imazethapyr was applied at 10 g ai ha^{-1} as a pretreatment on the OPF residue mulches at 3.5 t ha^{-1} as described previously. Two weeks after ornamental plants were transplanted into pots containing 3 kg soil, the imazethapyr-treated OPF mulch was applied on top of soil. Ornamental plants were irrigated with 300 mL of water from the top of pot daily and applied with 10 g organic fertiliser weekly for optimal plant growth. Visual quality of ornamental plants was assessed at 4, 8 and 12 WAT. Ratings on a scale from 1 to 10 were assigned to each plant considering plant size (3 points), foliage greenness (3 points), foliage fullness (2 points) and flowering (2 points). A rating of 1 represented dead plants. Ratings of 2–3 represented poor quality with plants exhibiting severe phytotoxicity or nutrient deficiency symptoms. Ratings of 4–5 represented below-average quality with plants exhibiting phytotoxicity or nutrient deficiency symptoms. Ratings of 6–7 represented average qualities, and ratings of 8–9 represented good quality. A rating of 10 represented premium plant quality with large plant size, dense and dark green leaves and abundant flowers (Chen *et al.,*8). The data were expressed as percentages of their respective controls. The experiment was arranged as complete randomised design with five replicates repeated twice in time.

The percentage data of weed emergence, weed shoot biomass and visual score of ornamental plants were checked for homogeneity of variance before being subjected to analysis of variance. The data of both experiments were pooled for analysis because the repeat time (experiment conducted twice) was not significant. Means were compared using the Tukey test at 5% significance level.

RESULTS AND DISCUSSION

Imazethapyr was selected as potential pre-emergence herbicide and examined on three selected weed species commonly found in landscapes because its synergistic combination effect with OPF residue mulch was proven in our previous study (Dilipkumar *et al.,*12). Significant differences against weed inhibition were generally observed when subjected to different suboptimal rates of imazethapyr (Fig. 1).

The application of OPF residue powder without imazethapyr at 3.5 t ha^{-1} reduced goosegrass, slender cyperus and coat buttons seedling emergence by 20%, 0% and 58%, respectively. We suggest that the efficacy of the OPF residue powder on seedling emergence inhibition is species dependent with slender cyperus being the least sensitive to the OPF, and coat buttons being the most sensitive, followed by the goosegrass. When the OPF was treated with imazethapyr, antagonistic or synergistic effect depending on weed species and herbicide rate.

Fig. 1 depicts herbicidal activity of imazethapyr and imazethapyr-treated OPF residue mulch on goosegrass, slender cyperus and coat buttons 3 WAT. No benefit is derived from increasing rate of imazethapyr over 10 g a.i. ha^{-1} in combination with OPF on weed seedling emergence and growth inhibition. However, increasing the herbicide rate improves seedling emergence inhibition if applied alone. This may indicate the OPF can only bind 10 g a.i. ha^{-1} imazethapyr for the mass of OPF present.

Benefit is observed in applying imazethapyr at low rate of 10 g ai ha^{-1} in combination with OPF in terms of weed seedling growth inhibition probably owing to the mechanism of imazethapyr which acts as shoot inhibitor rather than root inhibitor (Vencill,30). Imazethapyr-treated OPF mulch at the low rate resulted in excellent growth inhibition, implying that the addition of OPF mulch improves the phytotoxic activity of imazethapyr. This finding suggests that the OPF mulch is a good carrier for imazethapyr because the OPF mulch contains 21% lignin and 33% hemicellulose (Lai *et al*.,18) which could act as a slow release carrier of imazethapyr. Authors also suggested that the pretreated OPF mulches enhanced inhibition of weed growth may be owing to the occurrence of synergistic activity between imazethapyr and allelochemicals (Dilipkumar *et al.*, 12) released from the OPF mulches. Alternatively,allelochemicals released by oil palm residues powders and imazethapyr may be competing for the same sites in the soil (Dilipkumar *et al.*, 12). As a result, more imazethapyr molecules are available for uptake by goosegrass seedlings as reported by Dilipkumar *et al*. (11) who studied the effects of soil types on phytotoxicity of pretilachlor in combination with sunflower leaf extracts on barnyard grass.

Imazethapyr is a weak acid with pKa value of 3.9 (Aichele and Penner, 2). The soil pH of 4.3 in the present study may lead to low desorption of imazethapyr in soil, thereby reducing leaching potential of imazethapyr which has low Koc value of 97–283 ml/g. In addition, the OPF mulches may prevent the loss of imazethapyr owing to leaching as the herbicide has high water solubility of 1,400 mg/L. Coat buttons seedlings were inhibited synergistically in term of emergence and growth when subjected to the imazethapyr-treated OPF mulch at low and moderate application rates. The late emergence of coat buttons in this study might provide it a better opportunity to absorb the accumulated imazethapyr, thereby increasing the herbicidal activity. Consequently, the herbicidal activity of the imazethapyr-treated OPF mulch on coat buttons was higher than that provided by the herbicide alone.

By contrast, the OPF mulch treated with the high rate of imazethapyr at 166 g ai ha^{-1}resulted in antagonism on inhibition of goosegrass and slender cyperus seedling emergence. The antagonistic activity may be owing to increased nitrogen level which could stimulate emergence of goosegrass and slender cyperus as reported by Cavers and Benoit (6). Imazethapyr is susceptible to microbial degradation (Huang *et al*., 16). Degradation of imazethapyr will increase nitrogen content in soil depending on application rate of the herbicide. For instance, Saha *et al.* (26) reported that imazthepyr application at a rate of 25 g ai ha^{-1} had no significant effects on soil ammonification and nitrification rate, but the level of ammonification significantly increased from 30 to 60 days at a rate of 100 g ai ha^{-1}. Application of 166 g ai ha^{-1} imazethapyr in the present study may have increased nitrogen level in soil owing to microbial degradation and stimulated the weed emergence. In addition, OPF mulch containing about 3.6% nitrogen content could be easily mineralised in the soil during microbial decomposition and provide free nitrogen availability to stimulate the germination of weed seeds which may explain antagonism on inhibition of goosegrass and slender cyperus.

The low rate of imazethapyr in combination with OPF mulch provided great inhibition of weed seedling growth. Phytotoxic effect of the pretreated mulch was subsequently tested on six ornamental plants representing different families. Table 3

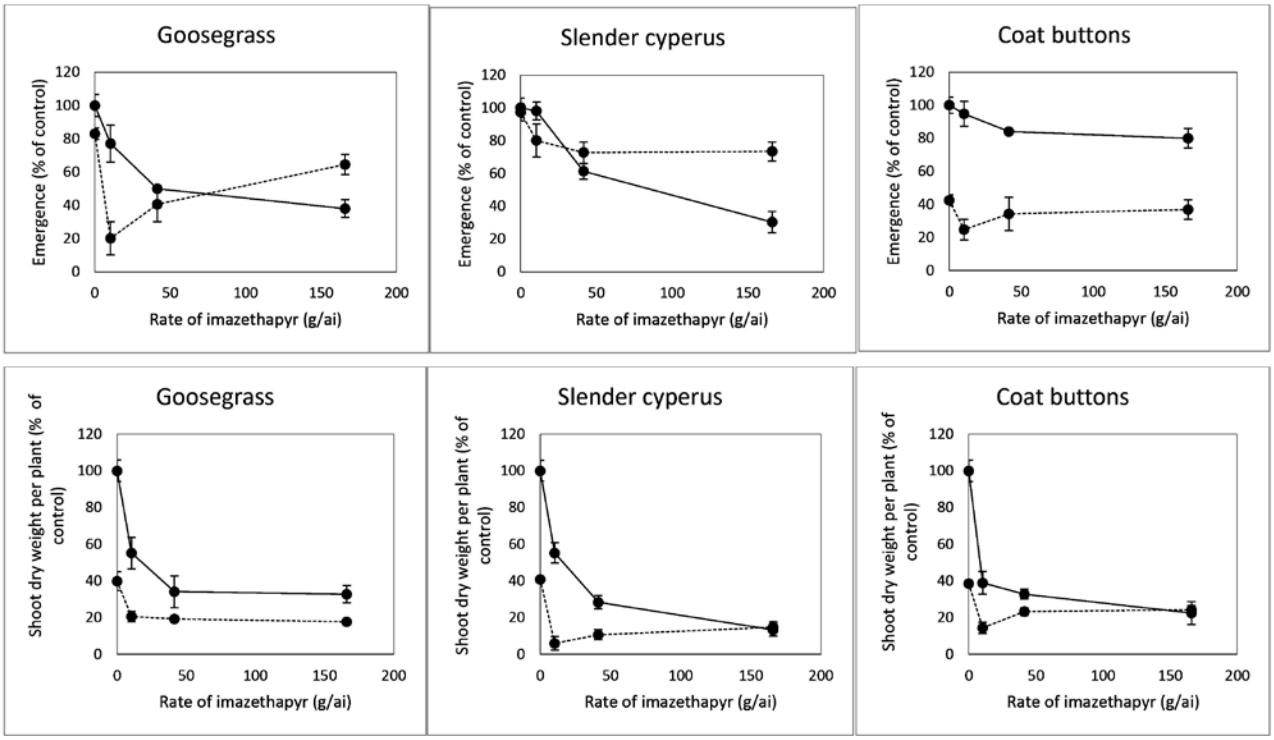


Fig. 1. Inhibitory effect of imazethapyr (—) and imazethapyr-treated oil palm frond residue mulch (- -) on seedling emergence and growth of goosegrass, slender cyperus and coat buttons three weeks after treatment. The untreated soil was served as control.

presents influence of the pretreated OPF mulch on visual quality of ornamental plants at 4, 8 and 12 WAT respective to their controls. The ornamental plants were selected in this study because they are commonly grown in Malaysia and have been popular plants for landscapes in recent years. Significant differences were observed in quality of ornamental plants when subjected to the pretreated OPF mulch. No adverse effect was provided bythe pretreated OPF mulch on the growth quality of *Aloe humilis* (L.) Mill. (cactus)*, Codiaeum variegatum* (L.) Rumph. ex A. Juss. (puding)and *Euodia suaveolens* var. *Ridleyi* (Hochr.) Bakh. f. (euodia). These ornamental plants exhibited good visual quality which is comparable with untreated plants. *Jasminum grandiflorum* L. (jasmine)was slightly affected with some yellowish leaves after being subjected to the pretreated OPF mulch. However, jasmine plant size responded positively to the pretreated OPF mulch, although overall plant visual quality did not improve compared with untreated plants. Similar results were reported with gardenia cultivar August Beauty (Richardson *et al*., 25), in which the growth was slightly improved when mulched with mini pine bark nuggets. These positive effects may be attributed to less fluctuation in soil temperature or higher soil moisture in mulched plots (Chen *et al*., 8). Moreover, the OPF mulch with approximately 3.6% nitrogen content could be easily mineralised in the soil during microbial decomposition and help boost the growth of most woody ornamental species.

However, only two species of ornamental plants, *Aloe vera* (L.) Burm. f. (*Chinese aloe*) and *Wrightia antidysenterica* (L.) R.Br. (coral swirl) had visual quality below 7 when subjected to the imazethapyr-treated OPF mulch as moderate phytoxicity was observed from 4–12 WAT. Applying the pretreated OPF mulch to the coral swirl could reduce plant size, foliage greenness and number of flowers with visual quality of 6.4, 6.3 and 6.0 at 4, 8 and 12 WAT, respectively. Similarly, Grichar *et al*. (15) reported that acifluorfen, bentazon, imazethapyr and lactofen caused castor stunting which ranged from 5%–46%. *Chinese aloe* also had low visual quality ranging from 4.5–5.0 at 4–12 WAT. The adverse effect of imazethapyr-treated OPF mulch to Chinese aloe was evident with yellowish leaves, necrosis and stunted growth.

We conclude that the OPF mulch treated with imazethapyr at low rate of 10 g ai ha^{-1} acted synergistically and provided great inhibition of

Table 3. Visual quality of ornamental plant respective to their controls at various weeks after treatment (WAT) with imazethapyr incorporated into oil palm frond residue mulches.

Ornamental plant	4 WAT	8 WAT	12 WAT
Wrightia antidysenterica	79 ab (6.4)	82 b (6.3)	73 b (6.0)
Jasminum grandiflorum	88 b (7.0)	92 bc (7.9)	92 c (7.1)
Aloe humilis	98 b (8.3)	101 bc (9.4)	102 c (9.7)
Aloe vera	55 a (4.7)	57 a (4.5)	54 a (4.6)
Codiaeum variegatum	97 b (8.4)	103 bc (8.4)	102 c (8.5)
Euodia suaveolens	103 b (7.5)	105 c (7.9)	100 c (8.4)

Value in parentheses is the rating of visual quality. Visual quality ratings on a scale from 1 to 10 were assigned to each plant considering plant size (3 points), foliage greenness (3 points), foliage fullness (2 points), and flowering(2 points), where 10 = excellent quality, 8 to 9 = good, 6 to 7 = average, 4 to 5 = below average, 2 to 3 = poor, and 1 = dead. ≥ 7 = commercially acceptable. Means followed by similar letters with the same column have no significant difference after analyzed by Tukey test at 5% of significant level.

weed seedling growth regardless of any bioassay species. Similarly, the weed emergence was greatly inhibited by the pretreated OPF mulch except for slender cyperus which is tolerant to the treatment. However, no benefit was observed from increasing rate of imazethapyr over 10 g ai ha^{-1} when being incorporated with the OPF mulch at 3.5 t ha^{-1}. On the other hand, ornamental plants such as jasmine, cactus, puding and euodia exhibited average to good visual quality after being subjected to the OPF mulch treated with the low rate of imazethapyr. By contrast, moderate phytotoxicity was observed for *Chinese aloe* and coral swirl at 4–12 WAT.

ACKNOWLEDGEMENT

Financial support was provided by the Ministry of Agriculture and Agro-Based Industry, Malaysia – MARDI.

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Received : October, 2018; Revised : January, 2019;
Accepted : January, 2019