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Full Length Article

Rice Husk Mat: Organic Mulch for Inhibition of Weed Seedling Emergence and Growth in Nursery Polybag

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Abstract

Abundantly available rice husk residues in Malaysia may be used as mulch that can result in reduced environmental pollution. Hence, this study was undertaken to determine the suitable thickness of rice husk mulch mat against selected weeds *i.e*., *Eleusine indica* (L.) Gaertn., *Ageratum conyzoides* (L.) L. and *Cyperus distans* L.f. These are highly invasive and abundant weeds found in oil palm nursery polybags. The experimental treatments consisted of 2-factors; (i) three levels of mulch mat thickness *i.e*., 2, 4 and 8 mm and two rice husk varieties *i.e*., MR 220 and MR 297. The results showed that increasing the mat thickness from 2 to 8 mm reduced the emergence, coverage, and biomass of weed seedlings at 6 weeks after treatment regardless of the rice variety used to produce the mat which was either MR 220 or MR 297. Punching tests were used to assess the mechanical properties of mats, while micrographs of the mats were captured to investigate the relationship between mat thickness and mechanical properties. Agglomerating agent was highly hydrated and nucleated on the rough surface of rice husk under 8 mm thick mats which led to the highest stress resistance and associated energy. However, intra-spaces of powdered rice husk were visible under 2- and 4-mm thick mats, resulted in decreased stress resistance and associated energy, thereby reducing the physical barrier of mats on test weeds. These findings imply that 8 mm thick rice husk mulch mat could be employed to control weeds in nursery polybags.

Keywords: *Ageratum conyzoides; Cyperus distans; Eleusine indica; Oil palm; Nursery; Rice husk mulch mat*

Introduction

Weeding is an important maintenance operation at both the pre and main-nursery stages in oil palm nurseries. During the main nursery stage, oil palm seedlings are transplanted and kept in large polybags for 8 months. Any weeds that grow in the polybags need to be pulled out by hand monthly (Tan 2011). Herbicide application is not recommended at this stage to reduce the risk of oil palm seedlings injury. Although hand weeding is the most extensively used and effective method of weed removal from nursery polybags, it is time-consuming and labor-intensive, resulting in significant maintenance expenses. Mathers (2003) stated that nursery producers, spent USD 500 to USD 4000 per acre on containers for manual weed removal, depending on the weed species eliminated. Besides, hand weeding frequency and weeding duration were 2.5 and 11 times higher in un-mulched plots than in pine bark mulched plots of planting bed, respectively (Marble *et al.* 2017).

A 517.1 million tons of rice was produced worldwide where over 90% of rice is grown in Asia, with China, India, and Indonesia accounting for 34, 28 and 8%, respectively; of total output in 2021 (FAOSTAT 2021). Rice husk is produced in large quantities as a byproduct of rice milling in rice-consuming countries (Bodie *et al.* 2019). The majority of paddy rice species yield 20% rice husk, 11% bran and 69% endosperm starch (Pode 2016). Malaysia, for example, produced 2.9 million metric tons of rice in 2021 (FAOSTAT 2021), resulting in 0.6 million metric tons of rice husk output. The majority of rice husk is currently underutilized or unused, posing a serious concern to the rice milling sector. Several methods of rice husk processing, such as onsite combustion for steam or power, open dumping or landfilling, produced huge amounts of pollutants such as smog, dust, and greenhouse gas emissions (Soltani *et al.* 2015).

Rice husk mulching, in addition to hand weeding, has been demonstrated to successfully reduce the emergence and growth of weeds (Altland and Krause 2014; Dilipkumar *et al.* 2015; Claramunt *et al.* 2020; Mas *et al.* 2021). The hard surface, high silicon content, difficulties breakdown by bacteria (Zou and Yang 2019) and allelopathic activity

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(Shirgapure and Ghosh 2020) of rice husk make it an excellent option for organic mulch in controlling weeds. This work attempts to transform rice husk agro-waste into mulch mat to combat weeds in nursery polybags. The study aimed to determine the appropriate thickness of rice husk residue mulch mat for inhibiting *Eleusine indica* (L.) Gaertn., *Ageratum conyzoides* (L.) L. and *Cyperus distans* L.f. due to their invasiveness and high abundance in oil palm nurseries. A punching test was carried out to determine stress resistance and associated energy to penetrate mats. Micrographs of the mats were obtained to investigate the relationship between mat thickness and mechanical properties.

Materials and Methods

Bioassay species

Seeds of common weed species found in oil palm nurseries, including *E. indica* (goosegrass), *A. conyzoides* (billy goat weed) represented grass weed and broadleaf weed, respectively, were collected from the Harumanis plot at UiTM, Perlis Branch with coordinate (6°45'56.''N 100°27'.66''E). Meanwhile, *C. distans* (slender cyperus) represented the sedges, and its seeds were collected from Bukit Kor, Marang (5°12'39.9"N 103°09'57.1"E). Seeds of each species were soaked in 0.2% potassium nitrate solution for 24 h to break seed dormancy before use. A preliminary seed germination test was conducted by placing the weed seeds in a Petri dish lined with moist filter papers, and the results confirmed that seed germination percentage of higher than 90%. Only seed coats of *E. indica* were scarified by using sandpaper to encourage germination (Ismail *et al.* 2002). Each seed was rinsed with distilled water and dried on tissue papers before being subjected to treatments.

Rice husk

Two different types of rice husk (*Oryza sativa* var. MR 220, *O. sativa* var. MR 297) were used. These rice husk residues were collected from Tanjong Piandang Area Farmers Organization and Kerian Farmers Organization. All the residues were dried under the sunlight in the open area for three days and kept in a universal oven at 50°C for three days. After it, the completely dried rice husk residue was ground into powder form (< 2 mm) by using a blender (Panasonic Model MX-9005) and sieved. The rice husk residue powder was packed, labeled and stored in a chiller at 10°C before use (Chuah and Lim 2021).

Preparation of 9 cm diameter rice husk mulch mat

The rice husk mulch mat was prepared according to the modified method as described by (Nasir 2020). A predetermined amount of agglomerating agent was dissolved in distilled water and the desired amount of crosslinking agent was added to produce a solution. The solution was poured into a 9 cm diameter mold, and rice husk powder was added to make a 2 mm thick mat. The mat was dried for 48 h in an oven at 50°C. The same procedure was performed for mats with a thickness of 4 or 8 mm.

Experiment 1: Rain shelter study

The experiment was conducted in the rain shelter, UiTM, Perlis Branch with the coordinate of 6º45'56.''N 100º27'.66''E. Temperature and light intensities ranged from 29–32℃ with 12 h photoperiod and photosynthesis photon flux density (PPFI) of 800 ± 1200 μE m^{-2} s^{-1}, respectively. Each polybag measuring the 9 cm diameter and 15 cm height was filled with 1 kg soil mixture that consisted of topsoil, organic matter (chicken dung) and sand at a ratio of 3:2:1. Twenty seeds of *E. indica* were sown evenly onto the moist soil surface. One day after sowing, each rice husk residue mulch mat with different thicknesses of 0, 2, 4 and 8 mm was applied onto the soil surface in the 9 cm diameter polybag. The same procedure was repeated for *A. conyzoides* and *C. distans.* The soils and mats were watered twice a day at 250 mL per polybag. All the treatments were arranged in a completely randomized factorial design with 15 replicates where factor one was rice variety (MR 220 and MR 297) and factor two was mat thickness (2, 4 and 8 mm). The polybag without rice husk residue mulch mat served as the negative control. The weed coverage and weed emergence were recorded weekly for 6 weeks. Seedlings were considered to emerge when the plumule attained a length of 1 mm. Weed emergence data were expressed as a percentage of respective controls. The percentage of the covered area by emerged weed in each polybag was measured with a circular quadrat using the formula as follows:

$$\text{Weed coverage} = \frac{\text{Surface area covered by weed per polybag}}{\text{Total soil surface area per polybag}}$$

Weed coverage data were then expressed as percentage of respective controls. Aboveground tissues of weed seedlings were harvested at six weeks after treatment. The plant tissues were dried for three days in the oven at 80°C (Amini *et al.* 2020) to obtain weed biomass.

Experiment 2: Punching test

The mechanical property of each mat sample was determined using a texture analyzer (Stable Micro System) based on the method of Claramunt *et al.* (2020) with modification. The analyzer's load cell has a maximum capacity of 500 N and the crosshead speed in the tests was 4 mm min^{-1}. The lateral surface of a 4.21 mm diameter cylinder with a mean of three thickness values determined in the penetration section is utilized to calculate the punching shear. The mechanical properties of mats were characterized based on a) stress, which was calculated by dividing the maximum force registered by the area of the section and b) the specific energy of the assay, which was calculated by multiplying maximum force registered with distance.

Experiment 3: Morphology of rice husk mat

Rice husk mats of each thickness were observed under a stereomicroscope (Olympus) fitted with a digital camera (Dino-Lite) at 12x, 13.5x, and 15x magnifications for 2-, 4- and 8-mm thick mats, respectively.

Statistical analysis

The weed emergence and weed coverage patterns were modeled using non-linear functions as follows:

$$Y = d/[1+\exp(-(t-t_{50})/b)$$

Where Y is the cumulative weed emergence/weed coverage at time t, d is the coefficients corresponding to the asymptotes (theoretical maximum for Y), b is the slope of the line, t_{50} is the time (day) required to give 50% weed emergence/weed coverage, and t is the time (day). All the data of punching force and associated energy, the percent data of biomass, emergence, and coverage of weeds at six weeks after treatment were tested for normality and homogeneity of variance before being subjected to two-way ANOVA by using SPSS version 26.0. Means were compared using Tukey's Honestly Significant Difference Test at 5% of the significance level.

Results

Experiment 1: Rain shelter study

Fig. 1 depicts the seedling emergence and coverage patterns of *E. indica* throughout six-week experiment. Seedling emergence of *E. indica* was much higher without the use of a mulch mat having a maximum emergence of 88%. Meanwhile, this was 27% under the 2 mm thick mat, 9 to 13% under the 4 mm thick mat and no emergence was observed under the 8 mm thick mat. The time it took for 50% of seedlings to emerge (te_{50}) increased with mat thickness and te_{50} was higher in the MR 297 rice variety than in the MR 220 rice variety. In both rice varieties, cumulative coverage of *E. indica* seedlings was greater without the use of the mulch mat. Without the application of mulch mat, the maximum seedling coverage was 86, 41 to 53% under the 2 mm thick mat, 14 to 16% under the 4 mm thick mat and 0% under the 8 mm thick mat. The time required for 50% seedling coverage (tc_{50}) increased with mat thickness; however, tc_{50} was similar for both rice varieties except for the 4 mm thick mat which was higher in MR 297.

Fig. 2 presents the seedling emergence and coverage trends of *A. conzyoides* during the six-week experimental period. Seedling emergence of *A. conzyoides* was shown to be greater without application of mulch mat, with 58% maximum emergence. Meanwhile, under the 2 mm thick mat, there was 11 to 14% and no emergence was observed under the 4- and 8-mm mat thicknesses. The te_{50} rose with mat thickness, and it was higher in the MR 297 rice variety than in the MR 220 rice variety. Similarly, without the use of the mat, the cumulative coverage of *A. conzyoides* seedlings was higher as compared to other thicknesses of mat. Without mulch mat treatment, the maximum seedling coverage was 16%, 6 to 7% under the 2 mm thick mat and 0% under the 4- and 8-mm thick mats. The tc_{50} increased with mat thickness as well; however, it was higher in MR220 than MR297 under the 2 mm thick mat.

Without mulch mat treatment, seedling emergence of *C. distans* was greater with a maximum emergence of 37%. Meanwhile, this was about 14% under 2 mm thick mat, 1 to 2% under 4 mm thick mat**,** whereas no emergence was recorded for 8 mm thickness of mat (Fig. 3). The te_{50} increased with mat thickness and te_{50} was greater under rice variety of MR 297 than MR 220. Likewise, cumulative coverage of *C. distans* seedlings was greater without the application of mat. The maximum seedling coverage was 10% without mulch mat treatment, 4 to 5% under the 2 mm thick mat, 1% under the 4 mm thick mat, and 0% under the 8 mm thick mat. The tc_{50} increased when increasing mat thickness. In addition, tc_{50} was greater in MR297 mat than MR220 mat irrespective of any thickness.

E. indica

At six weeks following treatment, there was no interaction ($P > 0.05$) between rice variety and mat thickness on the biomass of *E. indica* seedlings (Table 1). The only factor exhibiting a significant effect ($P < 0.05$) was the main effect of mat thickness. The degree of inhibition provided by different mat thicknesses can be classified in order of decreasing inhibition as follows: 8-, 4- and 2-mm thick mat when averaged across rice variety. It is interesting to note that a complete inhibitory effect was observed under the 8 mm thick mat, whereas the inhibition of seedling growth was 72 and 42% when treated with the 4- and 2-mm thick mats, respectively.

A. conzyoides

Similar to *E. indica*, interaction between rice variety and mat thickness had no significant ($P > 0.05$) effect on *A. conzyoides* seedling biomass at six weeks after treatment (Table 1). The main effect of mat thickness was the only factor that had a significant effect ($P < 0.05$). When averaged across rice variety, greater inhibition was exhibited by 4- and 8-mm thick mats as compared to 2 mm thick mat. Interestingly, seedling growth of *A. conzyoides* was inhibited under both 4- and 8-mm thicknesses of the mat.

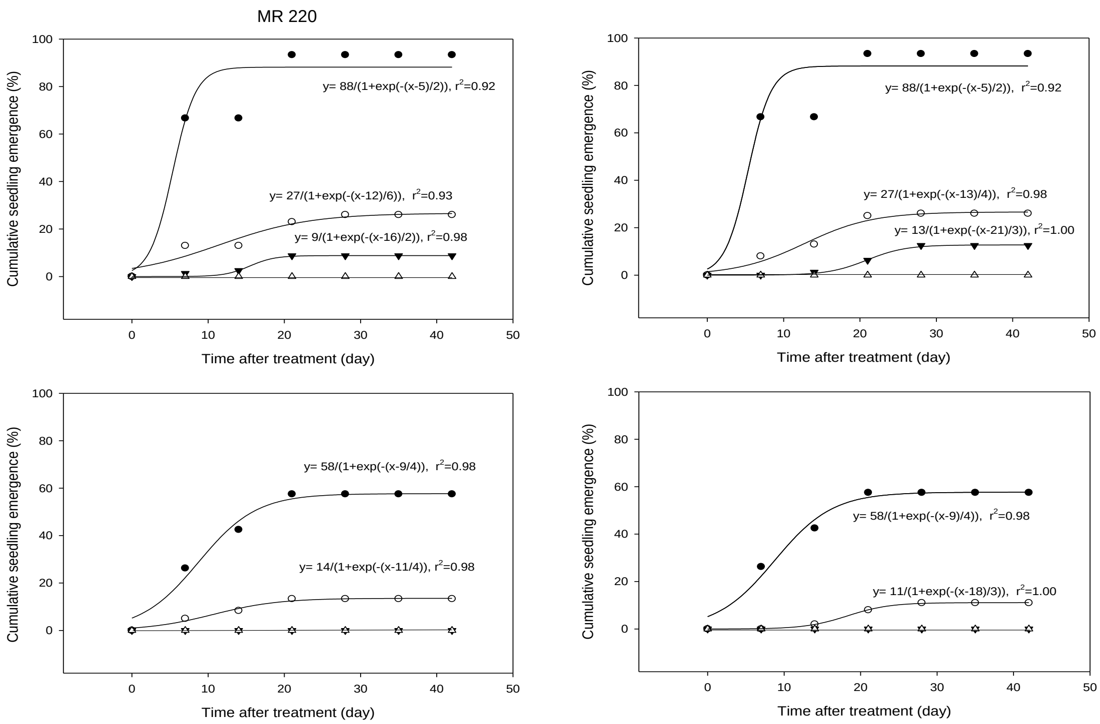

Fig. 1: Seedling emergence and weed coverage patterns of *Eleusine indica* treated with rice husk mat of MR220 and MR 297 at 0 (●), 2 (○), 4 (▼) and 8 (Δ) mm thickness

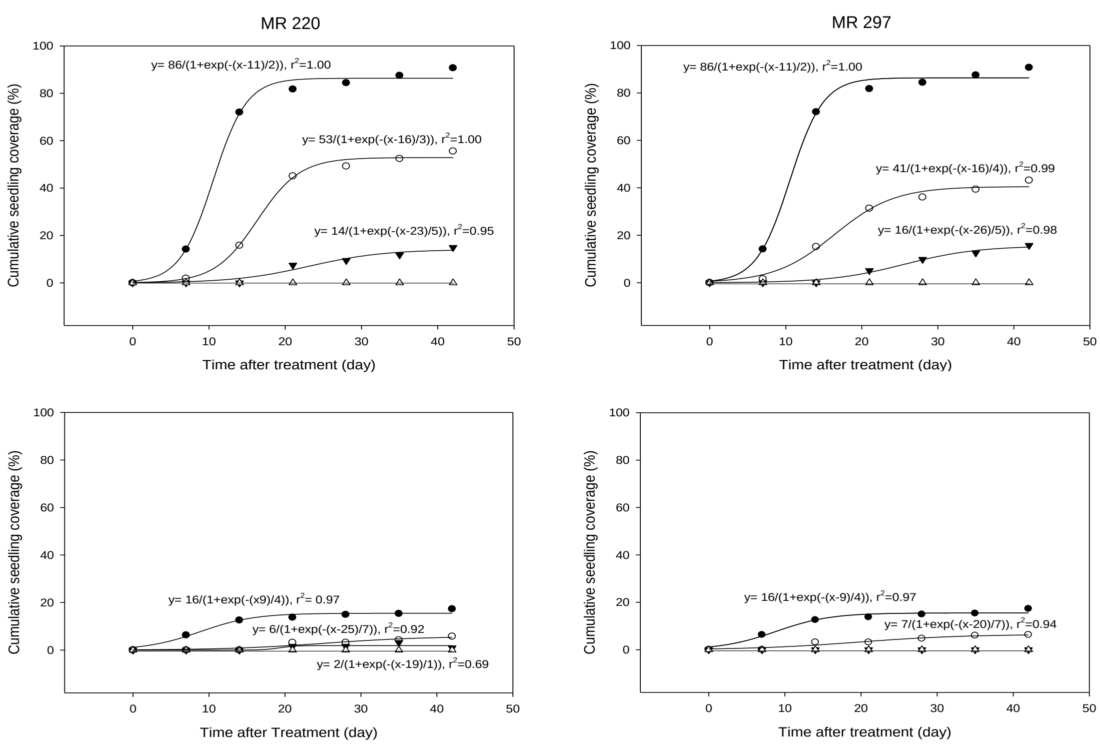

Fig. 2: Seedling emergence and weed coverage patterns of *Ageratum conzyoides* treated with rice husk mat of MR220 and MR 297 at 0 (●), 2 (○), 4 (▼) and 8 (Δ) mm thickness

Table 1: Main effect of rice husk mat thickness on seedling biomass of *Eleusine indica*, *Ageratum conzyoides* and *Cyperus distans* at six weeks after treatment

Mat thickness (mm)	Weed species	
	Biomass (% of control)*	
	E. indica	*A. conzyoides*
2 mm	58^{c}	49^{b}
4 mm	28^{b}	0^{a}
8 mm	0^{a}	0^{a}

*Means in the same column followed by the same letter indicate no significant difference at *P < 0.05* according to Tukey's test

Table 2: Interaction effect of rice husk mat thickness and rice variety on seedling biomass of *Cyperus distans* at six weeks after treatment

Rice variety	Mat thickness (mm)	Biomass (% of control)*
MR220	2 mm	86_{c}
	4 mm	1_{a}
	8 mm	0_{a}
MR297	2 mm	53_{b}
	4 mm	2_{a}
	8 mm	0_{a}

*Means in the same column followed by the same letter indicate no significant difference at *P < 0.05* according to Tukey's test

Table 3: Main effect of rice husk mat thickness on punching force and associated energy

Mat thickness (mm)	Stress (MPa)*	Energy(Jm)*
2 mm	1.01_{a}	0.06_{a}
4 mm	2.74_{b}	0.14_{a}
8 mm	5.31_{c}	0.41_{b}

*Means in the same column followed by the same letter indicate no significant difference at *P < 0.05* according to Tukey's test

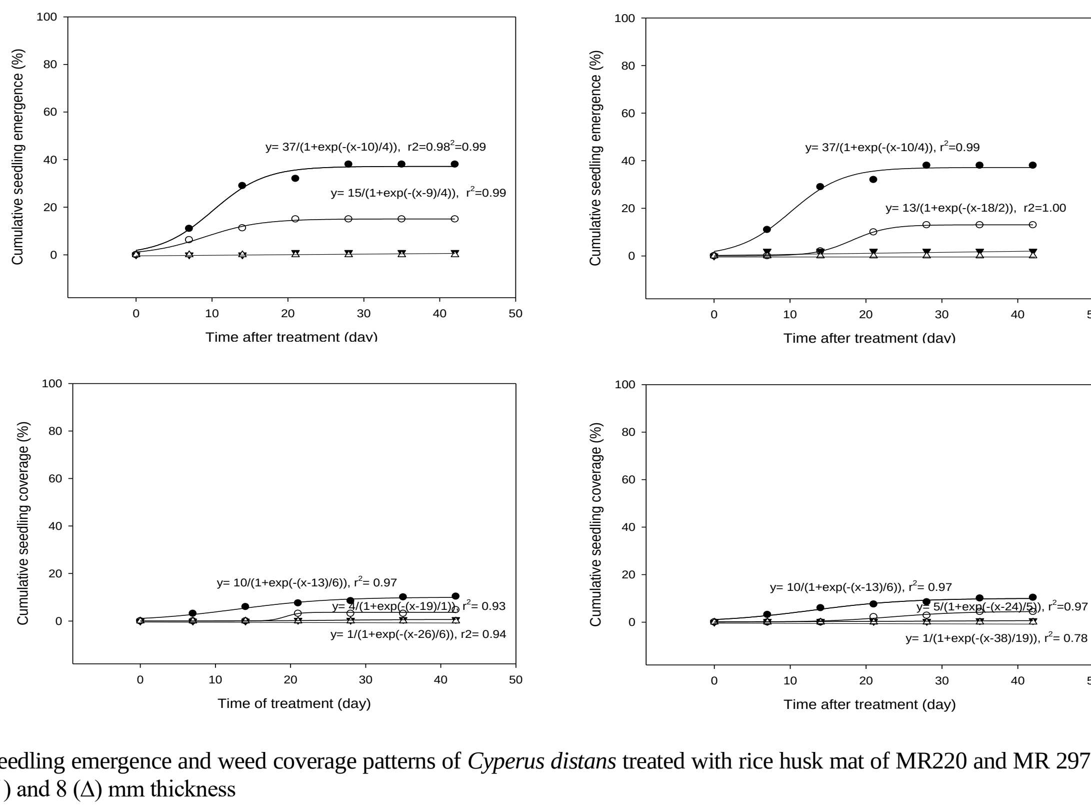

Fig. 3: Seedling emergence and weed coverage patterns of *Cyperus distans* treated with rice husk mat of MR220 and MR 297 at 0 (●), 2 (○), 4 (▼) and 8 (Δ) mm thickness

C. distans

It is worth noting that there was a significant interaction (*P < 0.05*) between mat thickness and rice variety on *C. distans* seedling biomass (Table 2). The rice variety MR 297 had a higher inhibitory effect (47%) compared to that given by MR 220 (14%) under the 2 mm thick mat. By contrast, the rice variety had no significant effect (*P > 0.05*) on the

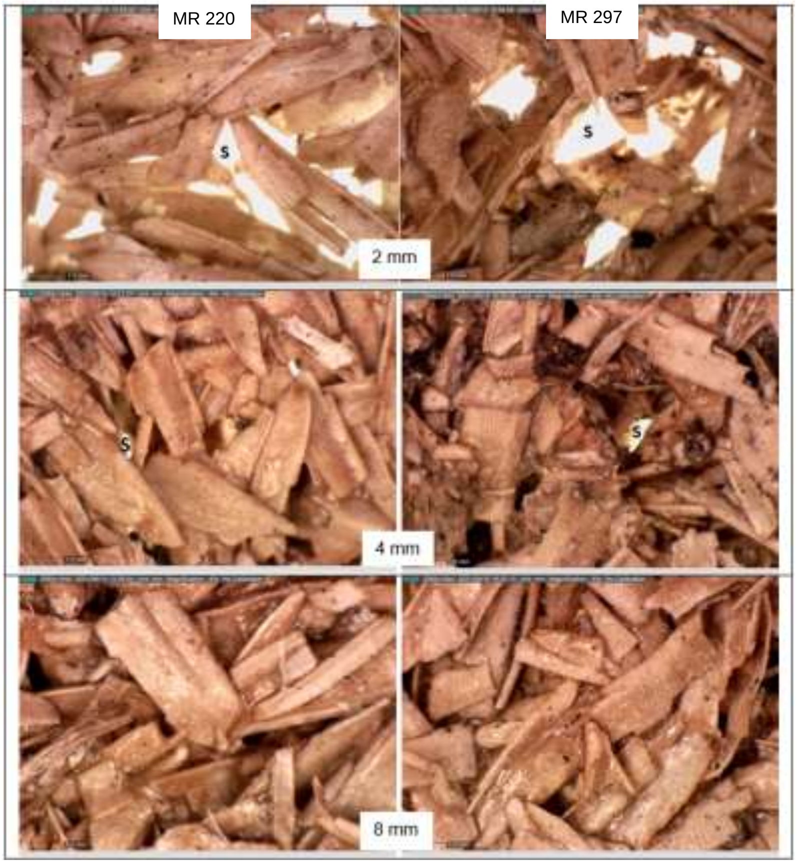

Fig. 4: Morphology of rice husk mat MR 220 and MR 297 at different thicknesses, s = intra-space of powdered rice husk

inhibition caused by the 4- and 8-mm thicknesses of mat that had 98 to 100% inhibition. In addition, no significant difference ($P > 0.05$) was found between 4- and 8-mm thick mats on inhibition of *C. distans* seedling growth.

Experiment 2: Punching test

Table 3 shows the punching force and associated energy of the mats obtained in punching tests. There was no significant ($P > 0.05$) interaction between rice variety and mat thickness in the mean stress and mean energy. Similarly, the main effect of rice variety was not significantly ($P > 0.05$) different. Despite within-mat variability of the variables measured, the thickness of the mat was a significant effect on the ANOVAs of the two variables. The 8 mm thick mat exhibited the highest means of stress and associated energy, followed by 4- and 2-mm thick mats.

Experiment 3: Morphology of rice husk mat

Fig. 4 presents the morphology of rice husk mat MR 220 and MR 297 at different thickness. It is clearly shown that a large degree of agglomerating agent was hydrated and nucleated on the rough surface of rice husk, indicating a compact frame. However, intra-spaces of powdered rice husk were visible under 2- and 4-mm thick mats, with the 2 mm thick mat having more intra-spaces as compared to that of 4 mm thick mat. By contrast, no intra-spaces were observed under 8 mm thick mat.

Discussion

The findings of this study showed that rice husk mulch mat can be used to suppress weeds in nursery polybags but the efficacy of the rice husk mulch mat for weed control is thickness dependent. It is suggested that weed control could be achieved in two ways with the rice husk mulch mat. First, it established a physical barrier on the surface, preventing test weeds from growing. With increasing mat thickness, the rice husk mat not only inhibited weed growth and emergence, but also slowed down seedling emergence and weed growth rates. Second, the allelochemicals released by the mats may inhibit weed seedling growth and germination. Two allelopathic momilactone A and B chemicals were discovered in rice husk by Quan *et al.* (2019). These allelochemicals have been shown to have a considerable inhibitory effect on the germination of weeds such as *Leptochloa chinensis* (L.) Nees, *C. difformis* L. (Yang *et al.* 2017), *Echinochloa cruss-gali* (L.) P. Beauv., and *E. colona*

(L.) Link (Kato-Noguchi and Ota 2013).

The present study indicated that mulch thickness plays a significant role in determining the effectiveness of mulch for weed control. In general, mulches can be effective for controlling weeds in containers, but they work best when applied to a depth of at least 250 mm (Saha *et al.* 2020). Several studies have been conducted to investigate the potential of rice husk residues for weed control when applied as mulch (Dilipkumar *et al*. 2015). For instance, Altland and Krause (2014) reported parboiled rice hulls applied at 130 mm depth in nursery containers inhibited the establishment of bittercress (*Cardamine flexuosa* With.) and liverwort (*Marchantia polymorpha* L.) completely. However, rice husk mulch at 8 mm depth failed to inhibit weed growth including bittercress (*Cardamine hirsuta* L.), crabgrass (*Digitaria* spp.), mulberry weed (*Fatoua villosa*) and creeping woodsorrel (*Oxalis corniculate* L.) (Witcher and Poudel 2020).

Surprisingly, the 8 mm thick rice husk mat in the present study was able to provide total inhibition of *E. indica*, *C. distans* and *A. conzyoides*, implying that the addition of agglomerating agent could enhance the physical barrier of rice husk, thus improving weed control efficiency. Similarly, large crabgrass (*Digitaria sanguinalis* L. (Scop.), red-root pigweed (*Amaranthus retroflexus* L.) and prickly lettuce (*Lactuca serriola* L.) were inhibited by 65 to 86% when subjected to rice husk hydomulch at a thickness of 5 mm (Claramunt *et al.* 2020). The rice husk hydomulch at a thickness of 190 mm, on the other hand, was effective in inhibiting rhizome sprouting and shoot emergence of several perennial weeds when compared to the non-mulched control treatment, with the control obtained being the highest for *Paspalum dilatatum* Poir, followed by *Sorghum halepense* Pers., *Cynodon dactylon* (L.) Pers. and *C. rotundus* L. (Mas *et al*. 2021).

Punching tests were performed to determine the mechanical characteristics of the mat. It is presumed that germinated weed seedlings can overcome the rice husk mulch mat layer by penetrating it directly. Therefore, punching tests could reveal the resistance of mats to being penetrated by the weed seedlings. Micrographs of the mats were further captured to investigate the relationship between mat thickness and mechanical property. The intra-spaces of powdered rice husk observed under 2 and 4 mm thick mats most likely have partly decreased stress resistance and toughness of mats, thereby reducing the physical barrier of mats on test weeds. As a result, the 2 and 4 mm thick mats could not inhibit the weeds effectively. Furthermore, *A. conyzoides* has been demonstrated to be strongly photoblastic, with less than 10% germination reported in darkness (Yuan and Wen 2018). Meanwhile, light could promote *E. indica* germination, albeit it is not required for seed germination (Chauhan and Johnson 2008). The intra-spaces of powdered rice husk most likely allowed light penetration, resulting in the emergence of seedlings of *E. indica* and *A. conyzoides*. By contrast, intra-spaces were not visible under 8 mm thick mat and thus permitted high punching resistance without light penetration which led to complete weed inhibition.

Conclusion

In summary, the current findings highlight the importance of using organic mulching materials such as rice husk and developing innovative strategies for their application in the weed control of oil palm nursery polybag to reduce the nursery activity's reliance on laborious and time-consuming hand weeding. A rice husk mulch mat with a thickness of 8 mm completely inhibited the test weeds. A study on the biodegradability of rice husk mat warrants further investigation to reveal its persistence under field conditions.

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Author Contributions

Associate Professor Dr. Chuah Tse Seng and Muhammad Ammar Yunus contributed to the study conception and design. Material preparation, data collection and analysis were performed by Muhammad Ammar Yunus. The first draft of the manuscript was written by Muhammad Ammar Yunus and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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