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PERFORMANCE OF UMAR-SRIMAT ON SOIL WATER CONSERVATION AND WEED CONTROL IN SYSTEM OF RICE INTENSIFICATION

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Graphical abstract

Abstract

Weed emergence is among the most important problems in system of rice intensification (SRI) due to extensive planting geometry of at least 25 × 25 cm and moist environment, thereby leading to water loss by means of evaporation from the broad space as a result of the extensive planting geometry, and transpiration by the weeds. This reduces the additional water saving which affect the potential of SRI water productivity. It also reduces rice crop yields up to 70% if there is no weed control attempted. Nowadays, weed is being controlled by manual weeder which is labour demanding, while motorized weeders overcome the problem but still, it able to remove the weeds before rice canopy closure or 30 days after transplanting (DAT). This research was designed to evaluate the performance of UMAR-SRImat on soil moisture conservation and weed control. UMAR-SRImat was made using flaked rice straw and biodegradable adhesive. The design was laid out using randomized complete block design (RCBD) with three treatments [without soil cover (T1), SRImat (T2), UMAR-SRImat (T3)] and three replications. The analysis was conducted using analysis of variance (ANOVA). Volumetric moisture content (VMC) was determined at 18 and 25 DAT. Weeds were observed and recorded to determine the weed dry weight and weed control efficiency at 20, 40 and 60 DAT. Plant height per hill was measured at 30 and 50 DAT, likewise, the number of tillers were counted at 30 and 50 DAT. The result of VMC showed that UMAR-SRImat significantly conserved water higher than the control treatment at 18 and 25 DAT of 3100.0[a] and 2680.0[a] m^3/ha, respectively. The effectiveness of UMAR-SRImat mulched was 100% at 20 DAT 99.64% at 40 DAT and 97.99% at 60 DAT. This research revealed that UMAR-SRImat mulch could retain soil moisture and suppressed weeds up to 60 DAT.

Keywords: Bio-composite technology, sustainable farming, rice yield, moisture content

1.0 INTRODUCTION

System of rice intensification (SRI) was started in 1980s by Fr. Henry de Laulanie, S.J., who was in Madagascar since 1961 from France, working with Malagasy farmers for 34years in order to progress their Agricultural systems especially rice cultivation, which is the steady food of the people in Madagascar [1]. Despite the facts that SRI practice produces higher yield up to 100% or more, saves water up to 50%, which have been confirmed in more than 50 countries in the world [2], particularly Malaysia, still, SRI farming experienced different type of problems like irrigation system, water supply, weed management and pest prevalence.

The total amount of irrigation water or water requirement under SRI system of farming have been reported by different authors with different results. In Iraq, the amount of water used in SRI farm was 21600 m^3/ha, but water used for non SRI was 34500 m^3/ha [3]. Also, comparative study was conducted between SRI and conventional system, and found that SRI used irrigation water volume of 10,981 – 13,055 m^3/ha while the conventional system used 13,999 – 17,805 m^3/ha [4]. However due to the influence of SRI aspects, make weeds to grow in large amount [5]. For instance, transplanting of single seedling per hill delayed the attainment of the rice plant to canopy closure [6]. This will cause evaporation of soil water from bare soil. Therefore, the soil water evaporation reduces the advantage of water saving gained by SRI practice, likewise, competition between the weeds and the rice crops as well as transpiration by the weeds also affect the water saving in SRI practice. Therefore, weed transpiration and water evaporation needs to be controlled by providing effective weed management strategy. One of the essential approaches is mulching.
Mulching is the covering of soil to make a physical barrier for reducing soil moisture evaporation, suppressing weeds, sustaining a good soil structure and preventing plants from soil pollutions [7] which may be in the form of organic or inorganic. Natural mulches are derived from animal and plant materials that can serve as alternative to other forms of mulches by sustaining soil organic matter and tilth (Particle size, moisture content, degree of aeration, rate of water infiltration and drainage into abbreviated term) [8], giving shelter and nourishment to soil biota and earthworms [9].

Biodegradable as well as photodegradable plastic mulches were manufactured due to the influences of pollution and removing and disposing of plastic films [10]. This is one of the main environmental, agronomic and economic complications in agriculture. The use of soil plastic cover or mulch has being increased gradually in agricultural sector due to the advantage of increase in soil temperature, decrease in insect pests, reduction in weed infestation, effective use of nutrients in the soil, moisture retention and higher yield output [10]. Similar statements have been revealed by strength compared to UMAR-SRImat without LGE. This may also affect it efficiency on the soil water conservation and the weed management.
[11] on using plane rice straw as mulching material, leading to the following advantages; less burning of rice straw by the farmers in order to stop the release of toxic substances in to the environment, rise in soil temperature, addition of carbon content, supplying of nutrients, improving of soil structure, suppression of weeds, soil and water conservation and erosion control.

Weeds are the main constraints in reducing rice yields, globally. Jacob & Syriac [12] reported that weeds compute severely with the rice crops in their early growth phases than the future, which lead to the slow growth and development of the crops and finally reduction in yield. Yield losses caused by weeds differ from a location to another. It depends on the weed flora and the method of weed management system practiced by the farmers. Rice crop sustained their growth by the same water, nutrients and solar radiation needed by the weeds. Weeds affect rice plants growth development by competing for light, nutrient, water and carbondioxide during it growing stages [13-15]. This may be due to the limited supply of the survival element, as their interaction caused competition for the resources.

Nowadays, mechanical hand weeder (conoweeder or rotating hoe) is being used for weed control in SRI up to 40 DAT which is labour intensive. The application of row weeding machine has overcome the problem of the hard labour, but it only controls the weeds up to 30 DAT [16] starting from 10 DAT with interval of 10 days due to the height of the rice plants [17] and the sideways growth of the vegetative portion of the rice plants, which are being injured by the motorized weeding machine (Haden *et al*., 2007). Again, due to the design of the motorized weeder, it cannot be used to suppress all the weeds within the rows, leading to hurtful competition to the rice plants. After the weeding operations using manual weeder or motorized weeder some of the infested weeds will be able to grow again from the roots, mostly, rhizomatous weeds.

There is a need or it is necessary to utilize rice straw for mulching but instead of using plane rice straw, it should be mulching material processed from rice straw. This will also improve the structure and fertility of soil apart from the mulching effects. Umar-SRImat is a bio-mulching material made up of rice straw and biodegradable adhesive. This research was designed to evaluate the performance of UMAR-SRImat on soil moisture conservation and weed control.

2.0 EXPERIMENTAL

The treatments consist of two mulching materials as soil cover, i.e. SRImat [18] and UMAR-SRImat. Two UMAR-SRImat were used in this study, because one of the UMAR-SRImat was incorporated with Lemon Grass Extract (LGE) for insect repellent which affected it The treatments trial comprised of four treatments and three replications (T1-No soil cover, T2-SRImat cover, T3- UMAR-SRImat cover without LGE and T4- UMAR-

SRImat cover with LGE). The experimental field was designed using a randomized complete block design (RCBD) with four treatments and three replications. The total area of the study site was 8.2 m × 8.9 m (72.98 m^2). The size of any single plot was 1 m × 1 m (1 m^2 area). Recent developed single seedling tray with seedling capacity of 924 seedlings was used for raising the seedlings up to 8 days [19]. Three blocks containing 4 plots each were made manually. Single seedlings per hill were transplanted in each plot using 8 days old seedlings at 30 cm × 30 cm planting geometry. Nine seedlings were transplanted per plot, 36 seedlings per block and a total of 108 seedlings for all the three blocks. Gap filling of the unrecovered seedlings was done. Irrigation water was applied based on demand after hairline cracks appeared on the soil surface as a result of drying of the soils, in order to maintain moist environmental condition. The soil was not allowed to be flooded continuously unless through frequent natural rainfall. Weeds and soil moisture content of each treatment plot were controlled according to treatment design as stated above, to avoid competition between rice plants and weeds for nutrients, water, carbon dioxides and solar radiations, and to void evaporation of soil water from the bare soil.

Soil moisture content of each plot was measured and recorded (at 18 and 25 DAT) after the appearance of hairline cracks by means of Pro Check which was attached to a sensor. This measurement was done to determine the amount of available moisture content of each plot after the appearance of the hairline cracks in the unmulched plots. The number of weeds (weed density) was collected from 0.09 m^2 in each treatment plot at 20 40 and 60 DAT. The weeds were oven dried for 48 hrs at 70^0 C [20], weighted by means of weighing balance, weed dried weight was recorded and finally the weed dry weight ratio was calculated. Weed control efficiency (WCE) (%) was calculated using weed dry weight ratio (WDWR) as shown in equation 1 [18]. Number of tillers and plant height per hill were randomly selected from 3 hills of each treatment plots at 30 and 50 DAT during the growing stages. The plant height was measured from the base of the plants up to the tips of the highest leaf of the central tillers using a measuring tape. Average value of the number of tillers and plant height were calculated and recorded. SPSS statistical analytical package (version 21) was used to analyse the data collected using analysis of variance (ANOVA). Means were compared using Duncan assumption to determine the significant differences among the diverse treatments.

$$WDWR = \left(1 - \frac{T_{dt}}{T_{dc}}\right) \times 100 \qquad (1)$$

Where;

T_{dt} = dry weight of weeds in a mulched plot

T_{dc} = dry weight of weeds in unmulched plot

3.0 RESULTS AND DISCUSSION

3.1 Soil Moisture Content

The main application of maintaining constant flooded water in conventional system of rice farming is to sustain the rice plant growth and development and to avoid weed emergence in paddy field. The depth of constant flooded water ranges from 5 cm to 10 cm height which is equivalent to 500 m^3/ha to 1000 m^3/ha depending on the rice growing stages. Considering the amount of water evaporated or loss from bare soil up to 25% to 50% of the whole amount of water applied to the farm [21] and the ability of rice crop to grow and develop under 80% level of soil moisture content [22], there is a need to maintain un-flooded water to reduce water loss and to control the weeds as well as to conserve the soil water by mulching technique. Mulch conserves soil moisture by preventing the evaporation of soil water from the soil surface. In this study both SRImat and UMAR-SRImat mulched plots significantly contributed in retaining higher volume of soil water than the unmulched plots treatments (Table 1).

Table 1 Volumetric moisture content as affected by soil cover

Treatments	18 DAT (m^3/ha)	25 DAT (m^3/ha)
T1	2070.0^b	2223.3^b
T2	3150.0^a	2710.0^a
T3	2916.7^a	2810.0^a
T4	3100.0^a	2680.0^a
LCD	0.05	0.05
CV	16.9	10.6
Mean	2809.17	2605.83

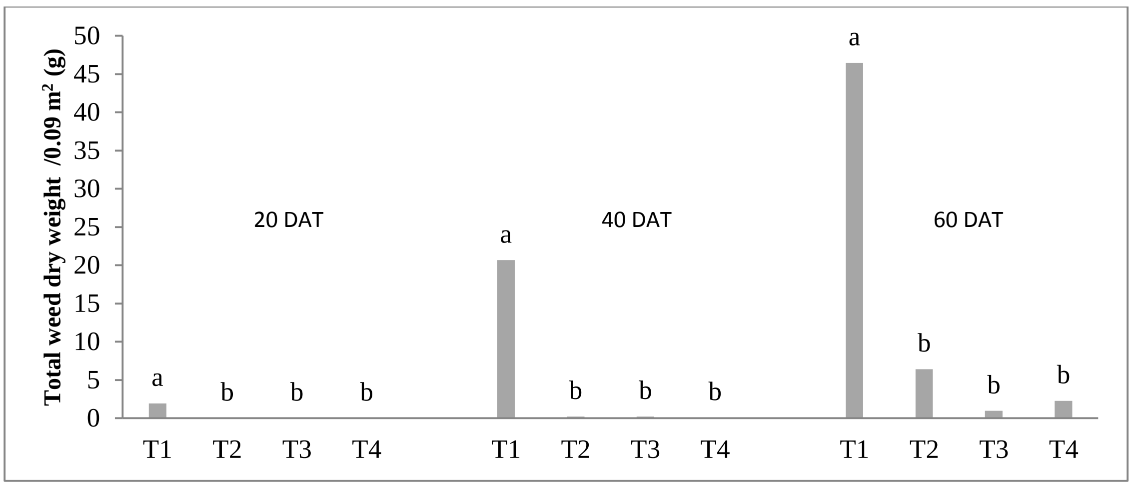
Note: No soil cover (T1), SRImat cover (T2), UMAR-SRImat cover without LGE (T3), UMAR-SRImat cover with LGE (T4).

Means followed by different alphabet along the same column are significantly different at P≤0.05.

All the mulched treatment plots (T2, T3, and T4) at 18 and 25 DAT depicted no significance difference between one another (Table 1). Similar result was reported by Chen [23] on retaining of higher moisture content using polythene mulch. The retaining of soil moisture in the mulched plots may be due to the less evaporation of the soil water [11] and transpiration from the weeds which reduces water productivity [4]. Spreading of plain rice straw [11] has some limitations over SRImat and UMAR-SRImat due to its loosely packed structure, when spread in the SRI farm. Therefore, sun light will be able to reach the soil surface to serve as energy for photosynthesis to take place, which lead to weed infestation. Hence, soil moisture will be able to evaporate from the soil surface as well as transpire from the infested weeds which lead to less water productivity. Therefore, this study revealed that both SRImat and UMAR-SRImat conserved soil moisture in SRI Field with significant reduction in the amount of water used due to less evaporation [11] from the soil and transpiration by the weeds.

3.2 Weed Dry Weight

Total weed dry weight depicted significant ($P \leq 0.05$) differences between the treatments because of SRImat and UMAR-SRImat mulch (Figure 1). However, there were no significant differences in total weed dry weight of all the weed classes between T2, T3 and T4. At 20 DAT the mulched treatment plots (T2, T3 and T4) depicted the least total weed dry weight (0g, 0g, and 0g/0.09m^2 respectively) while the plots without soil cover gave the highest total weed dry weight (1.94 g/0.09m^2) as shown in Figure 1. At 40 DAT the mulched treatment plots (T2, T3 and T4) gave the least total weed dry weight (0.22g, 0.26g, and 0.07g/0.09m^2 respectively) while the plots without soil cover gave the highest total weed dry weight (20.66 g/0.09m^2) (Figure 1). Likewise, at 60 DAT the mulched treatment plots (T2, T3 and T4) gave the least total weed dry weight (6.42g, 0.95g, and 2.27g/0.09m^2 respectively) while the plots without soil cover gave the highest total weed dry weight (46.47 g/0.09m^2). Similar results were reported on significant increase of weed dry weight in unweeded plots than the weeded plots [5, 15, 24]. Therefore, the function of UMAR-SRImat mulched was effective in controlling the growth and development of weeds in SRI farming because of the significantly lower total weed dry weight at 20 DAT and 40 DAT (Figure 1). This may be due to the allelophatic effect of SRImat and UMAR-SRImat on progression or development of the associated weeds. The allelophatic effect may be due to the release of phenolic composites by rice straw in the soil which leads to control of weed growth [20, 25]. Research depicted that the most efficient way for controlling the most problematic weed in paddy farm is by using rice straw mulch [25]. Scattering of plain rice straw [11] has some limitations over SRImat and UMAR-SRImat due to its loosely packed structure when spread in the SRI farm. Therefore, sun light will be able to reach the soil surface to serve as energy for photosynthesis to take place which lead to weed infestation.



* Mean with different alphabet (a-b) are significantly different at $P \leq 0.05$

Figure 1 Total weeds dry weight variation under mulched and unmulched treatments

3.3 Weed Control Efficiency

Weed control efficiency was determined by weed dry weight ratio, which showed the degree of reduction of weed dry weight due to the effects of the treatments using SRImat and UMAR-SRImat. Weed control efficiency at 20, 40 and 60 DAT depicted significant differences at $P \leq 0.05$ between the plots without soil cover and the other treatments (T2, T3 and T4) (Table 2). Similarly, the weed control efficiency also showed that both SRImat and UMAR-SRImat had the highest degree of weed suppression than the unmulched treatment due to higher weed dry weight ratio in the mulched treatment plots; T2 (100%), T3 (100%) and T4 (100%) than T1 (0%) at 20 DAT; T2 (98.68%), T3 (98.79%) and T4 (99.64%) than T1 (0%) at 40 DAT; and T2 (98.68%), T3 (98.79%), and T4 (99.64%) than T1 (0%) at 60 DAT. Hence, the least weed control efficiency (0%) was shown by plots without soil cover (T1) at 20, 40 and 60 DAT (Table 2). similar results were found using mechanical weeding method at 42 DAT with highest WCE (89.42 %) in treatment plots with three times weeding and lowest WCE (0.00%) in unweeded plot [24]. The grain yield of SRI rice was significantly influenced by the mulch treatment plot (Table 2). Application of UMAR-SRImat as mulch for weed suppression (T4) recorded the highest grain yield (23.153 t/ha). It was compared with the other treatments (T1, T2 and T3) and found that significant differences exist between the treatments. This was due to the decrease in competition [14, 26] between the rice plants and the weeds for water, nutrients, solar radiation and carbondioxide leading to the effective growth and development of the SRI rice plant as well as higher grain yield.

Table 2 Trend of weed dry weight ratio (weed control efficiency) and rice grain yield

Treatments	Weed dry weight ratio (%)			Grain yield
	20 DAT	40 DAT	60 DAT	(t/ha)
T1	0	0	0	4.009[d]
T2	100	98.68	86.63	18.660[c]
T3	100	98.79	97.99	19.600[b]
T4	100	99.64	94.60	23.153[a]

Note: No soil cover (T1), SRImat cover (T2), UMAR-SRImat cover without LGE (T3), UMAR-SRImat cover with LGE (T4).
Means followed by different alphabet along the same column are significantly different at P≤0.05.

3.4 Plant Height

The plant height results presented at 30 DAT (Table 3) showed significant difference between unmulched plots (T1) which produced shorter plants (44.44 cm) than SRImat (T2) and UMAR-SRImat with LGE (T4) plot with longer plants of 49.96 cm and 48.42cm, respectively. The same trend of results was revealed at 50 DAT (Table 3). However, no significant differences exist between the unmulched and mulched treatment plots (T2, T3 and T4). The existence of the longer rice plants in the mulched plots at both 30 and 40 DAT was due to the better weed suppression by the mulches resulting to the availability or less competition of the survival elements (nutrients, sun light, water and space) between the weeds and the rice plants for effective growth and development [27]. Equivalent results were reported on the existence of shorter rice plants in the unweeded control treatment plots, and longer rice plants in the weeded treatments [14, 26].

Table 3 Impact of various weed control on plant height and number of tillers

Treatments	Plant height (cm)		Tillers/hill (No.)	
	30 DAT	50 DAT	30 DAT	50 DAT
T1	44.44[c]	56.61[b]	10.33[c]	18.44[b]
T2	49.96[a]	67.44[a]	23.89[a]	57.78[a]
T3	46.42[bc]	64.44[a]	16.11[bc]	50.67[a]
T4	48.42[ab]	67.22[a]	18.00[ab]	57.67[a]

Note: No soil cover (T1), SRImat cover (T2), UMAR-SRImat cover without LGE (T3), UMAR-SRImat cover with LGE (T4).
Means followed by different alphabet along the same column are significantly different at P≤0.05.

3.5 Tillers per Hill

The young seedlings transplanted in the field were able to develop well, and the number of tillers per hill recorded was high even with the variation of the environmental situation of the SRI field due to the influence of SRImat and UMAR-SRImat mulched treatment plots as shown in (Figure 2). At both 30 and 50 DAT the unmulched plot depicted lower average number of 10.33 and 18.44 tillers per hill, respectively, while the mulched plot of UMAR-SRImat with LGE (T4) showed higher average number 18.00 and 57.67 tiller per hill (Table 3). The effectiveness of the weed control treatments made the number of tillers per hill to be significantly higher in T2, T3 and T4 than T1 at both 30 and 50 DAT (Table 3) due to less competition between the weeds and the rice plants in term of solar radiation, nutrients, carbon dioxide and water. Parallel outcomes were revealed by [14]. While the unmulched plot with less weed control efficiency and severe weed competition depicted the lowest number of tillers per hill. This was also reported in previous researches [13, 26].

Figure 2 Seedling status in treatment four (T4) at 50 DAT

4.0 CONCLUSION

The research findings revealed the effectiveness of UMAR-SRImat mulches in retaining higher volume of soil water at 18 and 25 DAT, due to it significant difference between the covered plots and the control plot. This depicted the opportunity UMAR-SRImat on reduction of water evaporation from the soil surface and transpiration by the weeds. This will also, increased the existing water saving found in SRI farming, decreased the fuel or cost of pumping by decreasing the irrigation frequency.

The research results showed that the use of UMAR-SRImat mulch was effective in weed suppression under SRI farming. Because at 20 DAT UMAR-SRImat treatments depicted zero weed dry weight and highest weed control efficiency of 100% for T4. Likewise at both 40 and 60 DAT the mulched treatment plots depicted low weed dry weight, and highest weed control efficiency than the unmulched treatment. The higher grain yield produced by the mulched treatment plot indicated the effectiveness of UMAR-SRImat on weed management in SRI. Despite the changing of the environmental condition of the SRI field due to mulching effects, all the transplanted planted seedlings were able to raise and develop in good health condition.

This study will improve the existing water saving in SRI farming due to effective weed control, leading to less transpiration by the weeds in the mulched plots, less evaporation from the soil, thereby retaining the soil moisture, recycling of nutrients in to the soil, improving of soil organic matter by means of UMAR-SRImat degradation after some time. The degraded UMAR-SRImat will be serving as feed to the soil microbes and environmentally friendly. The utilization of rice straw is better than burning. Smaller particle size of the UMAR-SRImat makes it degrade or decompose faster into useful form and used by the soil organic matter.

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