Available online at www.sciencedirect.com

ScienceDirect

Agriculture and Agricultural Science Procedia 2 (2014) 353 – 360

Agriculture and Agricultural Science
Procedia

"ST26943", 2nd International Conference on Agricultural and Food Engineering, CAFEi2014"

Impact of Mulch on Weed Infestation in System of Rice Intensification (SRI) Farming

Aimrun Wayayok[a,b], Mohd Amin Mohd Soom[a,b], Khalina Abdan[a], Umar Mohammed[a,c,]*

[a]*Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[b]*Smart Farming Technology Research Centre, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*
[c]*Department of Agricultural Education, School of Vocational Education, Umar Suleiman College of Education Gashua, Yobe State, Nigeria*

Abstract

Weeds infestation is one of the major constrains of SRI due to wide planting geometry and moist environment, thereby reducing rice yield up to 69.15%. This study aimed at evaluating the effect of two mulching materials (rice straw SRImats and plastic) on management of weed infestation, and determining of seedling behaviour. The parameters used for the analysis of weeds were density, relative density, dry weight, relative dry weight, summed dominance ratio and control efficiency. The results revealed that weed density was significantly reduced with range from control plot (1950.67 No.) to the rice straw SRImats plot (33.00 No.).

Peer-review under responsibility of the Scientific Committee of CAFEi2014

Keywords: Soil cover; weeding; weed density ratio; weed dry weight ratio; single seedling

1. Introduction

Rice (*Orizasativa* L.) is among the most vital foods in Asia, particularly, Malaysia. Nevertheless, certain obstacles hindered Malaysia's food security to be achieved due to many reasons - the paddy field area remained unchanged more than 40 years ago, rapid growth of population resulted to advance domestic demand for rice (1.5 to 2.4 million tonnes), raised the import of rice from 167,000 to 1,070,000 tonnes, the falling of Malaysia's self-

* Corresponding author. +60163868134; +2348065455601; fax: +6038-9466425.
E-mail address: mohammed.umar49@yahoo.com

2210-7843
Peer-review under responsibility of the Scientific Committee of CAFEi2014
doi:10.1016/j.aaspro.2014.11.049

sufficiency in the previous decades up to 63% despite the yield increased by the conventional modern agricultural practices, as well as yearly decline in number of people participating in rice farming (CIIFAD, 2014a). These showed that there is a great challenge for increasing rice yield in order to achieve food security, through using of new methods and cultural systems in rice farming. SRI is an innovative methodology which increases rice yield by altering the management of soil, nutrients, plants and water (CIIFAD, 2014b). The components of SRI as stated by Satyanarayana et al. (2007), comprise of transplanting young seedling of less than 15 days old, single seedling per hill, wide planting geometry of 25 × 25cm or more, and moist soil condition at the vegetative stage. SRI has numerous advantages over the conventional system of rice farming. It increases rice grain yield by at least 50% (Lin et al., 2005), save seeds by at least 80 - 90% (Miyazato et al., 2010), save water by at least 50% (Satyanarayana et al., 2007), as well as reducing the cost of rice production (Tech, 2004).

The most important problem of SRI is weed infestation (Haden et al., 2007) due to the alternate wetting and drying (Krupnik et al., 2012), wider planting geometry of single seedling (25 × 25cm or more) and aerobic or moist environment (Singh et al., 2012). Study shows that weed competition in SRI farming has a significant influence in reducing the rice yields (Krupnik et al., 2012). Similarly, study reported that SRI yield reduction due to weed competition is up to 69.15% (Babar and Velayutham, 2012a). Water productivity which is one of the benefits of SRI is significantly reduced up to 38% compared to weed free plots (Krupnik et al., 2012) . This may be due to the influence of transpiration by the weeds in the non-weeded plots. Water, nutrients, sunlight and carbon dioxide are the main factors for which rice crops and weeds compete (Babar and Velayutham, 2012a; Babar and Velayutham, 2012b). SRI farming uses various methods of weed control such as competitive rice cultivars, flooding (Haden et al., 2007), herbicides application, hand weeding, mechanical weeding, mulching as well as integrated weed management (Latif et al., 2005; Randriamiharisoa, 2002) with different degree of success.

Presently, manual hand row weeder can be able to remove the weeds up to 40 days after transplanting (DAT), but is labour intensive. Row weeding machine solved the problem of the intensive labour, but it can only be able to work in SRI fields up to 30 DAT due to the lateral vegetative part of the rice crops, which is being damaged by the row weeding machine (Haden et al., 2007). Furthermore, due to the width of the weeders, it is not able to remove all the infested weeds within the rows, leading to harmful competition to the plants (IRRI, 2014). After the weeding operations using manual weeder or row weeding machine some of the weeds are able to regrow from their roots, particularly, rhizomatous weeds (IRRI, 2014). One of the added advantage of mechanical weeder is aerating of the soil during the weeding operation (Babar and Velayutham, 2012b), which allows oxygen to circulate within the soil (Dobermann, 2004). This added advantage of soil aeration can also be produced naturally by movement of soil microbe within the soils like tunneling of the soil to produce burrows by earthworm, which allows air to circulate deeper in to the soil, encouraging microbial nutrients cycling at deeper soil levels as well as deeper plant roots penetration into the soil section with higher moisture content (Bioflora, 2013). Earthworm also distributes nutrients and organic matter all over the soil region, produces higher soluble nutrients (worm cast) more than the original soil, secretes stimulant for plant growth, process 200 tonnes of soil per acre. Earthworm can survive in the absence of tillage operations, because frequent tillage can reduce 90% of the number of worm, burying the crop residue they feed on, destroy the vertical worm barrow and kill the worm outright (Bioflora, 2013).

SRI farming systems produced sustainable rice straw more than the required amount of rice straw that will cover the soil surface where 9.696 t/ha was (Prabha et al., 2011) and 8.261 t/ha (Babar and Velayutham, 2012) were reported, respectively. Research showed that 4 tonnes of rice straw can be used as soil cover on 1ha of land (Devasinghe et al., 2011). Rice straw can stay long in the field due to higher lignin and silica contents as well as low protein and digestibility (Hanafi et al., 2012). It has being identified as future natural herbicides because during its degradation (El-Shahawy et al., 2006; Kato-Noguchi and Ino, 2005) it releases phenolic compounds (caffeic, cinnamic, ferulic, p-coumaric, o-cowmaric and p-hydroxybenzoic acids) as the allelophathic compound (Chung et al., 2003; El-Shahawy and Zydenbos, 2010) for weeds suppression (Chung et al., 2003; Devasinghe et al., 2011). Rice crop vegetative part at maturity stage contains about 40% of nitrogen, 30-35% of phosphorus, 80-85% of potassium and 40-50% of sulphur(Hanafi et al., 2012). Thus, the nutrients contents of the rice straw will be recycled and used as organic fertilizer (Nader and Robinsons, 2010) as well as feeds for feeding the soil microbes (Bioflora, 2013) in the SRI fields, which increase the fertility of the soil especially potassium and nitrogen (Bird et al., 2002). Therefore, it leads to less application of nitrogen, less cost of production as well as low water pollution potential (Bird et al., 2002).

Information on weed control up to 40 DAT without damaging the lateral vegetative part of the SRI crops and at the same time conserving soil moisture content is crucial. The objective of this research is to evaluate the influence of straw mat known as "SRImat" and commercialized black plastic (CBP) on weed growth and seedling behaviour in SRI farming. This research aims to develop an effective and sustainable weed control strategy as well as seeking the possibility of minimizing moisture loss through transpiration by the weeds in SRI field.

2. Materials and methods

2.1. Experimental design

Experiment was conducted in the research field at Ladang 2, Universiti Putra Malaysia (*UPM*). A randomized complete design (RCD) with five treatments and three replications were used in the experiments. The total plot area is 20 m^2 and the size of each treatment plot was 1 m^2. The treatments comprise of two mulching materials (CBP and SRImat) as soil cover. Rice straw was collected from SRI farm at TanjungKarang, Selangor. The straw was first ground using Snova 3 horse power (HP) and 38,000 revolution per minute (RPM) super heavy duty commercial Blender (model SB2L), and then the ground straw was sieved through 19.54 mesh count per inchto reduce the small particles. Afterwards, 9.8 kg of the straw was measured, distributed uniformly in 1m^2 plastic net and then followed by sewing using thread and needle in order not to allow the movement of the straw in the net. The amount of rice straw used in the making of the SRImat was calculated at the rate of 4 tonnes ha^{-1}. The CBP was collected from the Institute of Tropical Forestry and Forest Products (*INTROP*) at *UPM*. The SRImat and the CBP were perforated with a space of 25 cm^2 for transplanting of single seedling per hillat 25 × 25 cm. The seedlings were raised with MR219 rice seed variety using newly developed single seedling tray which was recently produced. The treatments plots were five treatments and three replications (Table 1).

Table 1. Various treatments observed during this study.

Treatments	Descriptions
T1	plots without soil cover
T2	CBP with 0.19mm thickness
T3	CBP with 0.57mm thickness
T4	CBP with 0.95mm thickness
T5	SRImat with 2.0mm thickness

The experimental field was prepared manually with a hoe after two days irrigation and then the soil was irrigated again followed by rough leveling. The SRImat and the CBP were laid in the moist field using the RCD design as calculated statistically. Single seedlings were transplanted using 8 days old seedlings. The field was irrigated at the depth of 2-3cm using alternate wetting and drying (AWD) i.e. application of water to the field after the appearance of hairline cracked (Sinha and Talati, 2007; Uphoff, 1999) by the soil surface. The experiment was conducted under natural fertility of the field without applying insecticide and fertilizer.

2.2. Observations and measurements

Three types of weed were categorized as sedge, grass and broadleaf. Sedges have solid stems with cross sections as triangular, the leaves are long, flat and narrow which are arranged in set of three, and the roots have fibrous roots system, tubers as well as stolon or rhizomes for plant to grow (UC IPM, 2014). Grasses have narrow leaves, parallel veins, arranged in set of two; stems are usually rounded or flatten and hollow excluding the nodes where the leaves joined. Grasses have collar, ligules, sheaths, auricles, stolon or rhizomes and flowers (UC IPM, 2014). Broadleaves have single main vein with branches and wider leaves than sedges and grasses, and also different leaves arrangement, edges, shapes, vein and stalk as well as different grow habit (UC IPM, 2014). Number of tillers and weeds were collected at 24 DAT. The number of tillers was counted from 4 hills m^{-2} from each plot. The weeds sample was collected from 30 × 30cm to determine the weed density and dry weight. The weed samples were classified based on weed class (sedges, grasses and broadleaves), counted and dried for 48 hours at 70°C in an oven (Devasinghe et al., 2011).

2.3 Calculations and analysis

Weed density were computed using weed density ratio (WDR) Eq. (1). The contribution of the weed type to the weed community was determined using summed dominant ratio (SDR) computed using relative density (RD) and relative dry weight (RDW) as in Eq. (1)(Bhager et al., 1999). Weed control efficiency (WCE) was determined using weed dry weight ratio (WDWR) as shown in Eq. (5).

$$WDR = \frac{T_t}{T_c} \times 100 \tag{1}$$

$$SDR = \frac{RD + RDW}{2} \tag{2}$$

$$RD = \frac{density\, of\ a\, given\, weed\, type}{total\, density} \times 100 \tag{3}$$

$$RDW = \frac{dry\, weight\, of\ a\, given\, weed\, type}{total\, dry\, weight} \times 100 \tag{4}$$

$$WDWR = \left(1 - \frac{T_{dt}}{T_{dc}}\right) \times 100 \tag{5}$$

whereT_{dc} = dry weight of weeds in non-treated plots, T_{dt} = dry weight of weeds in treated plots, T_c = number of weeds in non-treated plots, T_t = number of weeds in treated plots

The data collected was analysed using analysis of variance (ANOVA) with SPSS statistical analytical package (version 21). Mean were compared using Duncan assumption to detect the significant differences among the various treatments.

3. Results and discussion

3.1 Weed density

There were variations in both the densities of different weed classes and total weed density (Table 2). Considering the weed classes, this study showed that sedges had the highest weed density in all the treatment than in grasses and broadleaves. Similar findings were also reported by (Haden et al., 2007) with sedges indicating the highest number in two of his experimental plots on all the three classes. The SRImat gave the least sedges weed density (29.33 m^{-2}) while the unmulched treatments gave the highest sedges weed density (1584.00 m^{-2}). This showed that SRImat can effectively suppress sedges weeds followed by CBP than the unmulched plots. However, there were no significant differences in sedges weed density between T2, T3, T4 and T5. Weed control at 24 DAT using SRImat and CBP mulched were significantly ($P \leq 0.05$) showed least weed density compared to the unmulched plots (Table 2). Similar results were also reported (Ramakrishna et al., 2006) on significant least weed infestation on polythene and straw mulched plots than unmulched plots. SRImat gave the least total weed density ratio followed by CBP whereas the unmulched treatment has the highest weed density ratio as shown in Fig. 1(a). This shows that the application of SRImat was effective in the reduction of total weed density followed by CBP than the unmulched plots. The effectiveness of SRImat on weed suppression may be due to the phenolic compounds released by the rice straw during its decomposition (Chung et al., 2003; El-Shahawy and Zydenbos, 2010) as allelophatic compound for weed suppression (Chung et al., 2003; Devasinghe et al., 2011).

Table 2. Number of weeds based on weed classes as influenced by soil cover in SRI farming at 24 DAT m^{-2}.

Treatments	Sedges (No.)	Grasses (No.)	Broadleaves (No.)	Total weed density (No.)
T1	1584.00	128.33238.331950.67^{a}		
T2	84.33	11.00	14.67110.00^{b}	
T3	73.33	11.00	14.67	99.00^{b}
T4	73.33	14.67	11.00	99.00^{b}
T5	29.33	0.00	3.67	33.00^{b}

Plot without soil cover (T1), CBP with 0.19mm thickness (T2), CBP with 0.57mm thickness (T3), CBP with 0.95mm thickness (T4), SRImat with 2.0mm thickness (T5).
Note: Means followed by different alphabet along the same column are significantly different at P≤0.05.

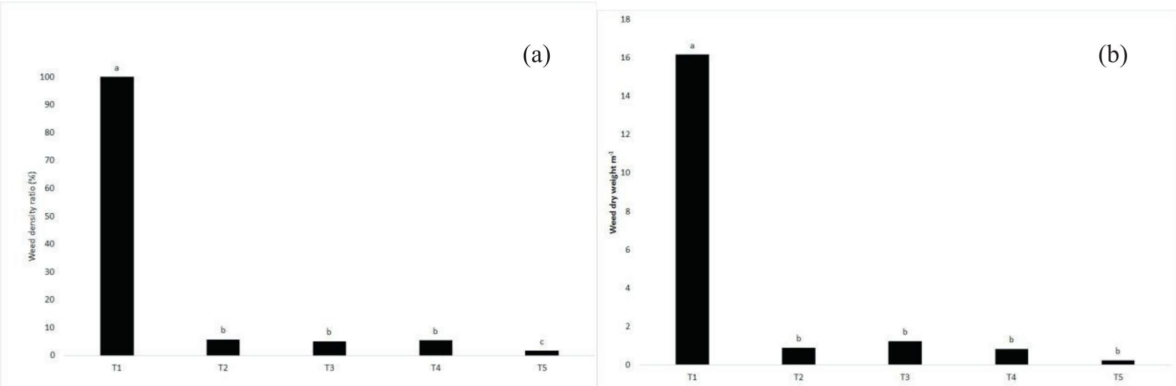

Fig. 1. (a) Weed density ration under mulched and unmulched treatments; (b) Total weed dry weight under mulched and unmulched treatments.

3.2. Weed dry weight

Soil cover in SRI field was found to affect dry weight of all the weed classes at 24 DAT in both SRImat and CBP mulch treatments (Table 3). The plots without soil cover showed abundant variety of weed classes than the covered plots. Mean dry weight of sedges (13.5667) was higher than both grasses (1.1367) and broadleaves (1.4667) in plots without soil cover (T1). A similar result has been reported on higher mean dry weight of sedges than both grasses and broadleaves in non-weeded plots (Haden et al., 2007). It was also recorded that the soil cover significantly ($P \leq 0.05$) reduced the dry weight of all the weed classes (sedges, grasses and broadleaves) compared to the plots without soil cover.

Total weed dry weight at 24 DAT showed significant ($P \leq 0.05$) differences among the treatments due to SRImat and CBP mulch (Table 3). However, there were no significant differences in total weed dry weight of all the weed classes between T2, T3, T4 and T5. But the SRImat plot gave the least dry weight (0.2567) while the plot without soil cover gave the highest dry weight (16.1700) as shown in Table 2. Therefore, the application SRImat cover was effective in weed suppression on growth and development of weeds in SRI farming due to the significant lower total weed dry weight at 24 DAT (Fig. 1(b)). This may be due to the allelophatic influence of SRImat on progression and development of the associated weeds. The allelophatic influence may be due to the release of phenolic compound by rice straw in the soil which leads to suppression of weed growth (Chung et al., 2003; Devasinghe et al., 2011; El-Shahawy and Zydenbos, 2010). Study showed that the most effective way for suppressing the most problematic weed in rice farming is by using rice straw mulch (Chung et al., 2003).

Table 3. Weed dry weight based on weed classes as influenced by soil cover in SRI farming at 24 DAT m^{-2}.

Treatments	Sedges (g)	Grasses (g)	Broadleaves (g)	Total weed dry weight (g)
T1	13.5667^{a}	1.1367^{a}	1.4667^{a}	16.1700^{a}
T2	0.5133^{b}	0.2200^{b}	0.1833^{b}	0.9167^{b}
T3	0.9900^{b}	0.1100^{b}	0.1467^{b}	1.2467^{b}
T4	0.4400^{b}	0.2567^{b}	0.1467^{b}	0.8433^{b}
T5	0.2200^{b}	0.0000^{b}	0.0367^{b}	0.2567^{b}

Plot without soil cover (T1), CBP with 0.19 mm thickness (T2), CBP with 0.57 mm thickness (T3), CBP with 0.95 mm thickness (T4), SRImat with 2.0 mm thickness (T5).
Note: Means followed by different alphabet along the same column are significantly different at $P \leq 0.05$.

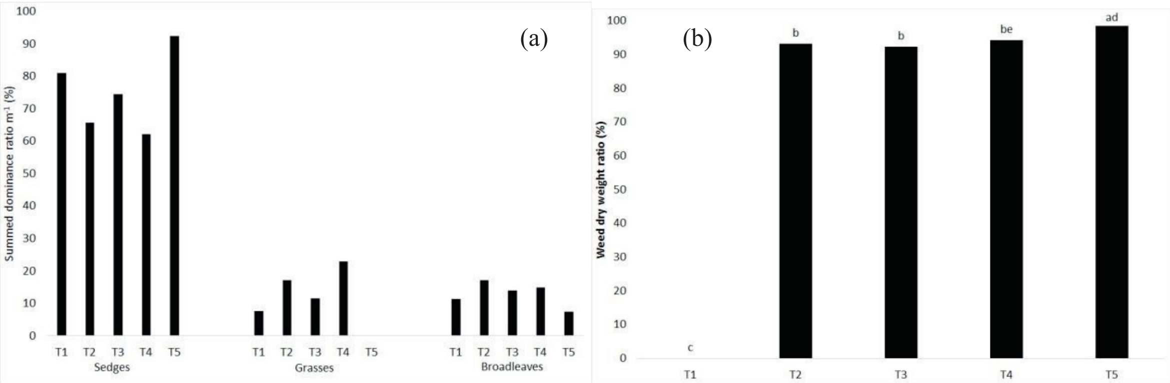

Fig. 2. (a) Summed dominance ratio based on weed classes as influenced by soil cover treatments in SRI farming m^{-2}; (b) Weed control efficiency derived from weed dry weight ratio as influenced by soil cover treatments.

3.3 Summed dominance ratio and weed control efficiency

The most abundant and dominant weed classes among all the treatments in the SRI field were sedges, due to the highest summed dominance ratio (ranging from T1 to T5; 81.04%, 65.77%, 74.43%, 62.15% and 92.50% respectively) than both the grasses and broadleaves as shown in Fig. 2(a).

Weed control efficiency was determined using weed dry weight ratio which shows the degree or effectiveness of reducing the weed dry weight of the different treatment plots. Weed dry weight ratio showed significant differences at $P \leq 0.05$ between the plots without soil cover T1 and the other treatments (T2, T3, T4 and T5) (Fig. 2(b)). Significant ($P \leq 0.05$) differences also exist between treatment T5 and treatment T2 and T3, but no significant difference exist with treatment T4 (Fig. 2(b)).The SRImat soil cover indicated the best result (98.53%) among the all treatments, followed by the CBP treatments (T2; 93.19%, T3; 92.20%, and T4; 94.18%). The least weed control efficiency (0%) was shown by plots without soil cover (T1). The study revealed that SRImat had the highest degree of weed suppression than the CBP and unmulched treatment due to highest weed dry weight ratio of SRImat plot (Fig. 2(b)).

3.4 Seedling behaviour

The transplanted seedlings were able to grow well despite the changing of the environmental condition of the SRI field due to the influence of SRImat and CBP soil cover treatments as shown in Fig. 3(a). The efficiency of the weed control treatments in T2, T3, T4 and T5 had made the number of tillers per hill to be significantly higher than T1 (Fig. 3(b)) due to less competition between the weeds and the rice crops in term of nutrients, water, light and carbon dioxide.

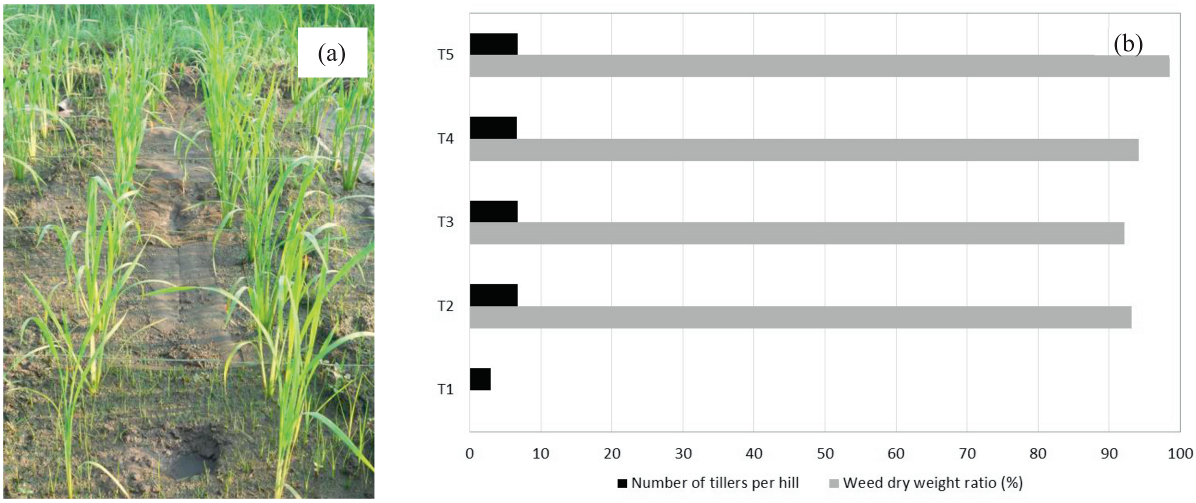

Fig. 3. (a) Seedling status at 24 DAT in the SRI field; (b) Average number of tillers hill^{-1} considering the weed control efficiency at 24 DAT m^{-2}.

4. Conclusions

This research showed that the use of SRImat mulch was effective in weed control under SRI farming. Dominance weed classes among the weeds in all the treatment were sedges based on summed dominance ratio in all the treatments. SRImat treatment had the lowest weed density, weed density ratio, weed dry weight, and highest weed control efficiency 98.50% indicating the effectiveness of SRImat on weed suppression. All the planted seedlings were able to grow well in good health condition. Due to increase in weed density, weed dry weight, highest weed ratio and lowest weed control efficiency 0% in the control treatment T1, seedling behaviour such as number of tillers of the rice crops was significantly reduced. This study will improve the existing water saving in SRI farming due to less transpiration by the weeds, recycled nutrients, feed the soil microbes and environmentally friendly.

Acknowledgements

This research was funded by the research grant from the Universiti Putra Malaysia RUGS vot no. 9376900. We wish to recognize the technical support and advice of Mr. Esrin and Mr. Azlan (SMART Farming Research Centre at UPM).

References

Babar, S.R., Velayutham, A., 2012a. Weed Management Practices on Nutrient Uptake, Yield Attributes and Yield of Rice under System of Rice Intensification.Madras Agricultural Journal 99(1/3), 51-54.
Babar, S.R., Velayutham, A., 2012b. Weed Management Practices on Weed Characters, Plant Growth and Yield of Rice under System of Rice Intensification.Madras Agricultural Journal 99(1/3), 46-50.
Bhager, R., Bhuiyan, S., Moody, K., Estorninos, L., 1999. Effect of Water, Tillage and Herbicide on Ecology of Weed Communities in IntensiveWet-Seeded Rice System.Crop Protection 18(5), 293-303.
Bioflora, 2013. Definition of Soil Microbe Groups. Retrieved 11/22, 2013, Retrieved from http://www.bioflora.com/soil-microbes.
Bird, J., Eagle, A., Horwath, W., Hair, M., Zilbert, E.,Van Kessel, C., 2002. Long-term Studies Find Benefits, Challenges in Alternative Rice Straw Management. California Agriculture 56(2), 69-75.
Chung, I., Kim, K., Ahn, J., Lee, S., Kim, S., Hahn, S., 2003. Comparison of Allelopathic Potential of Rice Leaves, Straw, and Hull Extracts on Barnyardgrass.Agronomy Journal 95(4), 1063-1070.
CIIFAD, 2014a. Report on S.R.I. Visit to Malaysia, July 1-9, 2011. Retrieved 4/25, 2014, Retrieved from http://sri.ciifad.cornell.edu/countries/malaysia/Malaysia_UphoffTripRept0711.pdf
CIIFAD., 2014b. SRI methodology. Retrieved 4 March 2014, Retrieved from http://sri.ciifad.cornell.edu/aboutsri/methods/index.html

Devasinghe, D., Premarathne, K., Sangakkara, U., 2011. Weed Management by Rice Straw Mulching in Direct Seeded Lowland Rice (Oryza sativa L.).Tropical Agricultural Research 22(3), 263-272.

Dobermann, A., 2004. A Critical Assessment of the System of Rice Intensification (SRI).Agricultural Systems 79(3), 261-281.

El-Shahawy, T. A., El-Rokiek, K., Sharara, F., Khalaf, K., 2006. New Approach to Use Rice Straw Waste for Weed Control. I. Efficacy of Rice Straw Extract against Broad and Narrow Leaved Weeds in Cucumber (Cucumis sativa L.).International Journal of Agriculture and Biology (Pakistan) 8(2), 262-268.

El-Shahawy, T. A., Zydenbos, S., 2010. Rice Straw as an Allelopathic Agent for Controlling Weeds. 17th Australasian Weeds Conference. New Frontiers in New Zealand: Together we can Beat the Weeds. Christchurch, New Zealand, 26-30 September, 2010.143-146.

Haden, V. R., Duxbury, J. M., DiTommaso, A., Losey, J. E., 2007. Weed Community Dynamics in the System of Rice Intensification (SRI) and the Efficacy of Mechanical Cultivation and Competitive Rice Cultivars for Weed Control in Indonesia.Journal of Sustainable Agriculture 30(4), 5-26.

Hanafi, E. M., El Khadrawy, H., Ahmed, W., Zaabal, M., 2012. Some Observations on Rice Straw with Emphasis on Updates of Its Management.World Applied Sciences Journal 16(3), 354-361.

IRRI, 2014. Weed control. Retrieved 5 February 2014, Retrieved from
http://www.knowledgebank.irri.org/ericeproduction/PDF_&_Docs/Weed_control.pdf

Kato-Noguchi, H., Ino, T., 2005. Concentration and Release Level of Momilactone B in the Seedlings of Eight Rice Cultivars.Journal of Plant Physiology 162(9), 965-969.

Krupnik, T. J., Rodenburg, J., Haden, V. R., Mbaye, D., Shennan, C., 2012. Genotypic Trade-Offs between Water Productivity and Weed Competition under the System of Rice Intensification in the Sahel. *A*gricultural Water Management115, 156-166.

Latif, M. A., Islam, M. R., Ali, M. Y., Saleque, M. A., 2005. Validation of the System of Rice Intensification (SRI) in Bangladesh.Field Crops Research 93(2-3), 281-292.

Lin, X., Zhou, W., Zhu, D., Zhang, Y., Yang, G., 2005. The Photosynthetic Rate and Water Use Efficiency of Leaves at Different Position at Panicle Initiation Stage under the System of Rice Intensification (SRI).Chinese Journal of Rice Science 19, 200-206.

Miyazato, T., Mohammed, R. A., Lazaro, R., 2010. Irrigation Management Transfer (IMT) and System of Rice Intensification (SRI) Practice in the Philippines.Paddy and Water Environment 8(1), 91-97.

Nader, G., Robinsons, P., 2010. Rice producers' Guide to Marketing Rice Straw. UCANR Publications.

Prabha, A. S., Thiyagarajan, T., Senthivelu, M., 2011. System of Rice Intensification Principles on Growth Parameters, Yield Attributes and Yields of Rice (Oryza sativa L.).Journal of Agronomy 10, 27-33.

Ramakrishna, A., Tam, H. M., Wani, S. P., Long, T. D., 2006. Effect of Mulch on Soil Temperature, Moisture, Weed Infestation and Yield of Groundnut in Northern Vietnam.Field Crops Research 95(2), 115-125.

Randriamiharisoa, R., 2002. Research Results on biological Nitrogen Fixation With the System of Rice Intensification. Assessments of the System for Rice Intensification (SRI). Proceedings of an International Conference, Sanya, China.

Satyanarayana, A., Thiyagarajan, T., Uphoff, N., 2007. Opportunities for Water Saving with Higher Yield from the System of Rice Intensification.Irrigation Science 25(2), 99-115.

Singh, N., Kumar, D., Thenua, O. V. S., Tyagi, V. K., 2012. Influence of Spacing and Weed Management on Rice (Oryza sativa) Varieties under System of Rice Intensification.Indian Journal of Agronomy 57(2), 138-142.

Sinha, S. K., Talati, J., 2007. Productivity Impacts of the System of Rice Intensification (SRI): A Case Study in West Bengal, India.Agricultural Water Management 87(1), 55-60.

Tech, C., 2004. Ecological System of Rice Intensification (SRI) Impact Assessment (2001–2003).Center for Study and Development of Cambodian Agriculture, Phnom Penh, May, http://ciifad.Cornell.edu/sri/countries/cambodia/camcedacimpact03.Pdf

UC IPM, 2014. Weeds Photo Gallery. Retrieved 5 February 2014, Retrieved from http://www.ipm.ucdavis.edu/PMG/weeds_intro.html

Uphoff, N., 1999. How to Help Rice Plants Grow Better and Produce More: Teach Yourself and Others.Ithaca, NY: CIIFAD, Cornell University.

Accepted for oral presentation in CAFEi2014 (December 1-3, 2014 – Kuala Lumpur, Malaysia) as paper 216.