Journal of Pharmacognosy and Phytochemistry 2019; 8(6): 2544-2549

Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(6): 2544-2549
Received: 12-09-2019
Accepted: 15-10-2019

Bavaji Gudi Shobha Rathod
Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

E Somasundaram
Department of Sustainable Organic Agriculture, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
Bavaji Gudi Shobha Rathod
Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Eco-friendly weed management in organic rice (*Oryza sativa* L.) production

Bavaji Gudi Shobha Rathod and E Somasundaram

Abstract

A Field experiment was conducted at wetlands farm of Tamil Nadu Agricultural University, Coimbatore during *rabi* 2014-15 (October-February) to study the best weed management practices in organic rice production. The experiment was laid out in randomized block design with three replication and ten treatments. The study revealedthat the application of rice bran @ 2 t ha^{-1} on 3 DAT followed by hand weeding on 35 DAT reduced the total weed density (17.00 No.m^{-2}) and total weed dry weight (3.87 g m^{-2}) significantly under organic rice production. Higher grain (5557 kg ha^{-1}) and straw yield (7207 kg ha^{-1}) of rice were obtained by mulching using biodegradable polyethelene sheets due to its suppressive effect on weeds but cost.All the treatments gave significantly higher grain yield than unweeded check. Taking in to consideration of economics, hand weeding on 15 DAT followed by Azolla inoculation on the same daywas remunerative in organic rice as it given the highernet returns (₹74,551 ha^{-1}) and benefit: cost ratio (2.24).

Keywords: Organic rice, weed density, weed dry weight, grain yield, net returns

Introduction

Rice (*Oryza sativa* L.) is the staple food of more than half of world population and is one of the leading cereal crop being grown in many regions of the world. The demand for organic food is steadily increasing both in the developed and developing countries with an average annual growth rate of 20-25 per cent (Ramesh and Subba Rao, 2009) [19]. India has tremendous potential to export organic rice to the international market. Domestic demand for organically rice grown is also gaining momentum. In India, the total area under certified organic cultivation is 4.72 million hectares (2013-14) including 3.99 million hectares under forest cover (www.apeda.gov.in) [25]. The area under organic rice is 11,292 ha and production is 22,674 million tonnes. In Tamil Nadu, organically rice cultivated in 5.8 ha and production is 14.77 million tonnes (NPOP, 2012) [26].

Weed control and soil fertility are the principal challenges associated with organic rice production. Weed management in organic farming is highly complicated and it would be appropriate to adopt various methods in combination rather than in isolation to manage these weeds from organic source depending upon the nature and intensity of weeds. Weeds compete with rice for moisture, nutrients, light, temperature and space. Furthermore, any delay in weeding will lead to increased weed biomass which has a negative correlation with yield.

Azolla reduces the intensity of light penetration, water evaporation and suppresses different weeds like *Echinochloa crus-galli*, *Cyperus spp*., *Paspalum spp*., (Biswa *et al*., 2005) [3]. Bhuiyan *et al.* (2014) [2] reported that higher rates of rice bran application produced a lower number of weed and weed weight which showed effective suppression of different weed species and beneficial to rice growth and yield. The mulch has the potential to discourage weeds and conserve soil moisture to facilitate direct seeding of rice as reported by Ehsanullah *et al*. (2014) [6]. It is important to understand that under an organic system weeds will never be eliminated but only managed. Weed control in organic systems focuses on management technique designed to prevent weeds, as well as the production of crop having vigorous enough to out-compete weeds and reduce the availability of resources to the weeds. Hence the present study was conducted for identifying an effective weed management technique for organic rice and to bring about substantial yield improvement of the crop.

Materials and Methods

A field experiment was conducted in O_4 block wetland farm of Tamil Nadu Agricultural University, Coimbatore during *rabi* 2014-2015 (October-February). The farm is situated in the Western Agroclimatic Zone of Tamil Nadu at 11°N latitude and 77°E longitudes at an altitude of 426.72 M above Mean Sea Level. The soil of the experimental field was having a pH of

8.3 and EC of 0.45 dSm^{-1}taxonomically classified as clay loam (Table 1). The experiment was laid out in randomized block design with three replications. The treatments comprised of ten different weed management practices *viz.*, Application of paddy straw @ 3 t ha^{-1} on 3 DAT + Hand weeding on 35 DAT (T_1), *Azolla* as dual crop with rice and incorporation on 35 DAT using power weeder (T_2), Hand weeding on 15 DAT and 35 DAT (T_3), Conoweeder 3 times on 20, 30, 40 DAT (T_4), Mulching with biodegradable polyethelene sheet (T_5), Intercropping mesta (*Hibiscus cannabinus*) with rice as paired row and harvested greens (T_6), Intercropping daincha (*Sesbania aculeata*) with rice as paired row cropping and incorporation on 35 DAT (T_7), Application of rice bran @ 2 t ha^{-1} on 3 DAT + Hand weeding on 35 DAT (T_8), Hand weeding on 15 DAT followed by azolla inoculation (T_9) and Unweeded check (T_{10}).

'CO (R) 50', a medium tall with New plant type rice variety with 135 days duration was used for the study. The 21 days old seedlings were transplanted with a row to row and plant to plant spacing of 22.5 X 22.5 cm. Stale seedbed technique, application of manures (Vermicompost, FYM), seed treatment with bio-inoculants and biological way of pest and diseases control was followed in all the treatments as per the recommended package of practices of Tamil Nadu Agricultural University (CPG, 2012) [5].

The rice bran and paddy straw was applied at 2 t ha^{-1} and 3 t ha^{-1}, respectively. They were spread on inter row spacing of rice field after 3 DAT. Fresh *Azolla* was inoculated after 5 days of transplanting (DAT) @ 1.0 t ha^{-1} in the respective treatment plots and water was maintained at 3-5 cm depth. At 35 DAT the *Azolla* was incorporated into the soil by using power weeder developed by Tamil Nadu Agriculture University, Coimbatore. Hand weeding on 15 DAT followed by *Azolla* inoculation on 15 DAT and left for multiplication. Biodegradable polyethelene sheet of 50 microns thickness was placed after transplanting of rice crop and a round hole was made on the sheet for the easy emergence of the tillering along the sides. The sheet was place throughout the critical crop weed competition period to control the weeds and removed after harvest as it can also be reused for the next crop period. The requirement of biodegradable polyethelene sheet was 8.3 g/m^2. *Sesbania aculeata* nursery was raised with a seed rate of 10 kg ha^{-1}. Seedlings were pulled out from the nursery plot on 15th DAS. Green manures were intercropped in T_7 with paired row planting of green manure in rice. Manual incorporation of daincha was done on 35th DAT. *Hibiscus cannabinus* nursery was raised with a seed rate of 15 kg ha^{-1}. Seedlings were pulled out from the nursery plot on 15th DAS. Mesta was transplanted as intercrop in T_6 in paired row with rice. Mesta was harvested before flowering for greens (vegetable) purpose. In the net plot area, five sample plants were selected randomly and tagged for recording biometric observations. The net plot produce was threshed and the grain and straw yields were recorded.

Weeds were sampled in each plot at 20, 30 and 50 DAT of the crop from an area of 0.5 m^2, counted and dried to constant weight at 70 ºC in hot air oven for 48-72 hours. Observations on weed count, weed density, weed dry weight, growth and yield of rice were recorded and the data were statistically analyzed as per the procedures suggested by Gomez and Gomez (1984) [9] for Randomized block design. Data on weed density showed high variation and hence they were subjected to square root transformation $\sqrt{(X + 2)}$ and analyzed statistically. Wherever the treatment difference was found significant, critical difference was worked out at 0.05 probability level. Treatment differences that were non-significant were denoted by 'NS'.

Table 1: Soil characteristics of the field at the inception of experiment

Particulars	Values	Method	Author(s)
Textural composition (Moisture free basis)			
Clay (%)	47.5	Robinson's international pipette method	Piper (1966)
Silt (%)	22.2		
Coarse sand (%)	11.9		
Fine sand (%)	18.4		
Texture	Clay loam		
Chemical composition			
Available N (kg ha^{-1})	216 (Low)	Alkaline permanganate method	Subbiah and Asija (1956)
Available P_2O_5 (kg ha^{-1})	16.9 (Medium)	Ascorbic acid method in ERMA colorimeter using red filter (660 nm)	Olsen *et al*. (1954)
Available K_2O (kg ha^{-1})	410 (High)	Flame photometric method (neutral normal ammonium acetate extraction) using potassium filter	Stanford and English (1949)
Organic carbon (%)	0.60	Chromic acid wet digestion method	Walkley and Black (1934)
Microbial population			
Total bacteria (CFU x 10^6 g^{-1} soil)	15.0	Nutrient agar	Collings and Lyne (1968)
Total fungi (CFU x 10^3 g^{-1} soil)	9.0	Martin`s rose Bengal agar	Martin (1950)
Total actinomycetes (CFU x 10^4 g^{-1} soil)	4.0	Ken Knight`s medium	Kenknight and Muncie (1939)

Results and Discussion

Weed flora

The weed flora observed in the experimental field was *Echinochloa colonum*, and *Echinochloa crus-galli* under grasses, *Cyperus difformis* and *Cyperus iria* under sedges and *Ammania baccifera, Eclipta alba* under broad leaved weeds. Altogether grasses especially *Echinochloa colonum* and sedges particularly *Cyperus difformis* were predominant, followed by broad leaved weeds comprising *Ammania baccifera* during the period of investigation. This might be due to weeds with higher growth vigour under a submerged condition at the initial stage of rice cultivation. Similar observations were reported by Madhu and Nanjappa (1995) [13].

Effect on total weed density

The density of total weeds was significantly affected by different weed control treatments in transplanted organic rice (Table 2). At 20, 30 and 50 DAT, total weed density was distinctly reduced (15.33, 31.67 and 17.00 m^{-2}) by application of rice bran 2 t ha^{-1}fb hand weeding. It was at par with hand weeding on 15 DAT fb azolla inoculation (15.86 m^{-2}) at 20 DAT and conoweeder incorporation thrice (34.67 and 35.33 m^{-2}) at 30 and 50 DAT. This was followed by hand weeding twice (43.33 and 33.33 m^{-2}) and mulching with biodegradable polyethelene sheet (45.33 and 50.50 m^{-2}) at 30 and 50 DAT. These results are in conformity with the findings of Gnanasoundari and Somasundaram (2014) [8] who reported that reduction of total weed density by application of rice bran at 2t ha^{-1} 3 DAT + HW on 35 DAT might be due to the control of weeds at the germination phase and significant reduction at later stages as late germinating weeds were controlled by one hand weeding at 35 DAT. The suppressive effect of rice bran application on soil surface under flooded conditions, might have increased the ratio of carbon dioxide to oxygen and redox potential levels had detrimental effects on seed germination and seedling emergence was reported by Forcella *et al.* (2000) [7]. Total weed density was conspicuously higher (65.33, 87.00 and 107.33 m^{-2}) in unweeded check (T_{10}) at 20, 30 and 50 DAT because no control measures were adopted in this plot at all the stages of crop growth.

Effect on total weed dry weight

The different weed management practices showed a significant effect on weed dry weight. At all stages of observation, the total weed dry weight (Table 2) was significantly lower in application of rice bran 2 t ha^{-1}fb hand weeding (4.05, 5.76 and 3.87 g m^{-2}) and it was at par with hand weeding on 15 DAT fb azolla inoculation (4.45) at 20 DAT. The same treatment was comparable with conoweeder incorporation thrice (9.00 and 9.97 g m^{-2}) and hand weeding twice (9.34 and 6.54 g m^{-2}) at 30 and 50 DAT. The total broad leaved weeds were less throughout the cropping period, it might be due to environmental factors, water management and cultural practices. In general, weed population density and total dry weight per unit area decrease as water depth increases. This is accordance with the findings of Bhagat *et al.* (1996) [1].The application of rice bran significantly decreased the total weed density and weed dry weight as compared with unweeded check was reported by Khan *et al.* (2007) [11]. Hand weeding on 15 DAT followed by azolla inoculation on the same day recorded lower number of total weeds with lesser biomass and also reduced the intensity of light penetration, water evaporation and suppressed different weeds like *Echinochloa crus-galli*, *Cyperus spp.*, *Paspalum sp.* which was in line with Biswa *et al.* (2005) [3]. Distinctly higher (25.06, 64.35 and 93.59 g m^{-2}) total weed dry weight was observed in unweeded check at 20, 30 and 50 DAT, respectively.

Growth attributes

Mulching with biodegradable polyethelene sheet registered significantly higher plant height (114.2 cm), number of tillers (228.8 m^{-2}), dry matter production (12976 kg ha^{-1}), leaf area index (2.30) at 120 DAT, respectively (Table 3) and it was par with application of rice bran at 2 t ha^{-1} on 3 DAT and hand weeding on 35 DAT, hand weeding on 15 DAT fb azolla inoculation and hand weeding twice. Mulches covered the surface of the soil, smothered the weeds by excluding light and providing a physical barrier to impede their emergence. The favorable environmental factors, reductions in light transmittance, temperature fluctuations and a physical barrier by the mulch cover recorded taller plants. This finding is in line with Singh *et al.* (2007) [20] who reported that plastic mulch covered the rows created unfavorable conditions (light and temperature) for growth.

Mulching with biodegradable polyethelene sheet recorded significantly higher tiller number resulting in higher dry matter production of crop which is in conformity with the findings of Ehsanullah *et al.* (2014) [6]. Tillering ability plays a vital role in determining rice grain yield. More number of tillers might be due to the more utilization of available nutrients because of the suppression of weed growth which resulted in higher grain yield. Taller plants with broader leaf area might have accumulated higher plant dry matter production and leaf area index (LAI). Unweeded check recorded lower plant height (79.5 cm), number of tillers (132.2 m^{-2}), dry matter production (6608 kg ha^{-1}) and LAI (0.94). This might be due to the higher competition of weeds which reduced the input availability to plants and hence reduced to a greater extent.

Table 2: Effect of different weed management practices on total weed density (No.m^{-2}) in organic rice production

		Treatments	Total weed density (No.m^{-2})			Total weed dry weight (gm^{-2})		
			20 DAT	30 DAT	50 DAT	20 DAT	30 DAT	50 DAT
T_1	-	Application of paddy straw @ 3t ha^{-1} on 3 DAT + Hand weeding on 35 DAT	6.34 (38.20)	7.15 (50.67)	6.15 (35.86)	3.28 (8.76)	3.47 (12.21)	3.77 (10.01)
T_2	-	*Azolla* as dual crop with rice and incorporation on 35 DAT using power weeder	6.51 (40.33)	7.30 (52.72)	7.66 (56.72)	3.46 (9.98)	7.06 (12.85)	3.85 (47.88)
T_3	-	Hand weeding twice on 15 DAT and 35 DAT	4.24 (16.00)	6.62 (43.33)	5.94 (33.33)	2.64 (4.95)	2.92 (9.34)	3.37 (6.54)
T_4	-	Conoweeder 3 times on 20, 30, 40 DAT	7.91 (60.52)	5.93 (34.67)	6.11 (35.33)	5.02 (23.16)	3.46 (9.00)	3.32 (9.97)
T_5	-	Mulching with biodegradable polyethelene sheet	6.14 (35.67)	6.77 (45.33)	7.25 (50.50)	3.33 (9.06)	3.76 (10.98)	3.60 (12.17)
T_6	-	Intercropping mesta (*Hibiscus cannabinus*) with rice as paired row and harvested as greens	7.48 (54.00)	8.82 (77.33)	10.02 (98.50)	4.71 (20.22)	9.36 (50.88)	8.53 (70.70)
T_7	-	Intercropping daincha (*Sesbaniaaculeata*) with rice as paired row cropping and incorporation on 35 DAT	7.02 (47.33)	7.54 (56.33)	6.38 (38.67)	3.78 (12.25)	6.72 (43.96)	6.78 (12.06)
T_8	-	Application of rice bran @ 2t ha^{-1} on 3 DAT + Hand weeding on 35 DAT	4.16 (15.33)	5.67 (31.67)	4.36 (17.00)	2.46 (4.05)	2.42 (5.76)	2.79 (3.87)
T_9	-	Hand weeding on 15 DAT followed by azolla inoculation	4.23 (15.86)	6.26 (38.67)	6.90 (45.56)	2.54 (4.45)	3.73 (9.28)	3.36 (11.95)
T_{10}	-	Unweeded check	8.21 (65.33)	9.35 (87.00)	10.46 (107.33)	5.20 (25.06)	9.78 (64.35)	8.15 (93.59)
		SEd	0.28	0.33	0.33	0.15	0.22	0.27

	CD (P=0.05)	0.60	0.70	0.69	0.32	0.46	0.56

Figures in parenthesis are original values, which are subjected to square root transformation (√x +2) before statistical analysis

Table 3: Effect of different weed management practices on growth attributes and yield in organic rice production

		Treatments	Plant height (cm) at harvest	Number of tillers (No.m^{-2})	Dry matter production (Kg ha^{-1})	LAI at harvest	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})
T_1	-	Application of paddy straw @ 3t ha^{-1} on 3 DAT + Hand weeding on 35 DAT	110.1	203.5	10722	1.99	4610	5989
T_2	-	*Azolla* as dual crop with rice and incorporation on 35 DAT using power weeder	101.2	168.9	9008	1.66	3898	5790
T_3	-	Hand weeding twice on 15 DAT and 35 DAT	112.0	207.9	11325	2.03	5020	6324
T_4	-	Conoweeder 3 times on 20, 30, 40 DAT	108.0	187.7	10197	1.93	4557	5831
T_5	-	Mulching with biodegradable polyethelene sheet	114.2	228.8	12976	2.30	5557	7207
T_6	-	Intercropping mesta (*Hibiscus cannabinus*) with rice as paired row and harvested as greens	96.0	157.5	8516	1.55	3642	5626
T_7	-	Intercropping daincha (*Sesbaniaaculeata*) with rice as paired row cropping and incorporation on 35 DAT	104.5	182.2	9628	1.79	4241	5790
T_8	-	Application of rice bran @ 2t ha^{-1} on 3 DAT + Hand weeding on 35 DAT	113.9	215.5	12356	2.13	5377	6858
T_9	-	Hand weeding on 15 DAT followed by azolla inoculation	112.3	215.5	11824	2.12	5020	6694
T_{10}	-	Unweeded check	79.5	132.2	6608	0.94	2774	4682
		SEd	9.7	17.5	948	0.17	371.2	561.2
		CD (P=0.05)	20.4	36.7	1992	0.35	779.9	1179.0

Yield of organic rice

Higher grain (5557 kg ha^{-1}) and straw yield (7207 kg ha^{-1}) was observed in mulching with biodegradable polyethelene sheet and at par with the application of rice bran at 2 t ha^{-1} on 3 DAT followed by hand weeding on 35 DAT (5377 and 6858kg ha^{-1}),hand weeding on 15 DAT followed by azolla inoculation (5020 and 6694kg ha^{-1}) and hand weeding twice on 15 DAT and 35 DAT (5020 and 6324kg ha^{-1}).This might be due to timely and effective control of weeds which resulted in increased growth and yield components. Higher soil temperatures increase nutrient availability, enhance nutrient uptake by roots, increases the number and activity of soil microorganisms, and speed up plant growth. This reflected in increased grain and straw yields (Table 3). The effective control of weeds starting from the early crop growth stage might have resulted in better growth and yield of rice. The variation in grain yield under different treatments was the result of variation in weed density and weed biomass. This result could be supported by the findings of Mubshar *et al.* (2012) [15].However, lowest grain and straw yield (2774 and 4682 kg ha^{-1}) was recorded under unweeded check. The minimum growth attributes and yield in unweeded check were results of severe weed competition by the uncontrolled weed growth throughout the crop period. Similar findings were noted by Gnanasoundari and Somasundaram (2014) [8].

Economics

From the economics point of view, the cost of cultivation, gross return, net return and benefit cost ratio was influenced significantly due to different weed control treatments in organic rice production (Table 4). Higher cost of cultivation was registered with mulching with biodegradable polyethelene sheet (₹1,26,396 ha^{-1}) and was followed by application of rice bran at 2 tha^{-1}fb hand weeding (₹69,326 ha^{-1}). It was moderate in application of paddy straw at 3 t ha^{-1}fb hand weeding (₹58,326 ha^{-1}). Lowest cost of cultivation was recorded in intercropping daincha with rice as paired row cropping and incorporation on 35 DAT (₹52,886 ha^{-1}). Because of highest cost of rice bran due to its economic importance as a feed to animal husbandry and expensive mulch lead to higher cost of cultivation.

Highest gross returns (₹1,49,011ha^{-1}) was recorded with the mulching with biodegradable polyethelene sheet and was followed by application of rice bran at 2 t ha^{-1}fb hand weeding (₹1,44,019ha^{-1}).The net return was markedly higher in application of rice bran at 2 t ha^{-1}fb hand weeding (₹74,693 ha^{-1}) and was followed by hand weeding on 15 DAT fb azolla inoculation (₹74,551 ha^{-1}). Significant improvement in grain and straw yield could have contributed to the higher gross and net return. Highest B:C ratio (2.24) was recorded with hand weeding on 15 DAT followed by azolla inoculation and hand weeding twice. Hand weeding twice had increased the grain and straw yield but cost of cultivation was more and so net income was reduced as compared to hand weeding on 15 DAT followed by *Azolla* inoculation on 15 DAT.

Mulching by using biodegradable polyethelene sheet recorded higher cost of cultivation, lowest B:C ratio (1.18) and net returns compared to unweeded check which is due to the higher cost of biodegradable polyethelene sheet and labour requirement for placing the sheet (Table 4). This findings are similar to Ehsanullah *et al.* (2014) [6] who reported that minimum benefit cost ratio of plastic mulch treatment was due to more cost of production.

Conclusion

From this study, it was concluded that, among the weeding methods application of rice bran @ 2 t ha^{-1} on 3 DAT followed by hand weeding on 35 DAT reduced the weed density and weed dry weight, increased the yield and net return significantly under organic rice production. Rice bran applied on flood water early after rice transplanting is easier to practice and adds little extra costs as it is a by-product of rice farming. Rice bran application effectively suppressed major paddy weeds without herbicide use and also increased the grain yield of rice. Therefore, this practice would be incorporated as an integral part of herbicide free organic rice farming.

Higher grain and straw yield of rice were obtained by mulching using biodegradable polyethelene sheets, which even effectively controlled weeds by suppressing the growth but cost. Taking in to consideration of economics, it is suggested to go for economically viable weed management practices in organic rice. Among all the treatments, hand weeding on 15 DAT followed by Azolla inoculation on the same day was remunerative in organic rice as it given the higher net returns and benefit: cost ratio. Further research under large scale weed management in organic rice is necessary to validate the practices.

Table 4: Effect of different weed management practices on cost of cultivation, gross return, net return (₹ ha^{-1}) and B:C ratio in organic rice production

		Treatments	Cost of cultivation (₹ha^{-1})	Gross return (₹ha^{-1})	Net return (₹ha^{-1})	B:C ratio
T_1	-	Application of paddy straw @ 3t ha^{-1} on 3 DAT + Hand weeding on 35 DAT	58,326	1,23,638	65,312	2.12
T_2	-	*Azolla* as dual crop with rice and incorporation on 35 DAT using power weeder	57,326	1,05,545	48,219	1.84
T_3	-	Hand weeding twice on 15 DAT and 35 DAT	59,926	1,34,359	74,433	2.24
T_4	-	Conoweeder 3 times on 20, 30, 40 DAT	65,526	1,22,082	56,556	1.86
T_5	-	Mulching with biodegradable polyethelene sheet	1,26,396	1,49,011	22,615	1.18
T_6	-	Intercropping mesta (*Hibiscus cannabinus*) with rice as paired row and harvested as greens	53,598	98,929	45,331	1.85
T_7	-	Intercropping daincha (*Sesbaniaaculeata*) with rice as paired row cropping and incorporation on 35 DAT	52,886	1,14,119	61,233	2.16
T_8	-	Application of rice bran @ 2t ha^{-1} on 3 DAT + Hand weeding on 35 DAT	69,326	1,44,019	74,693	2.08
T_9	-	Hand weeding on 15 DAT followed by azolla inoculation	60,326	1,34,877	74,551	2.24
T_{10}	-	Unweeded check	49,926	75,899	25,973	1.52

References

1. Bhagat RM, Bhuiyan SI, Moody K. Water, tillage, and weed interactions in lowland tropical rice: A review. Agricultural Water Management. 1996; 31(3):165-184.
2. Bhuiyan MKA, Mridha AJ, Ahmed GJU, Islam SA, Mamun MAA. Effect of rice bran application for eco-friendly weed control, growth and yield of lowland rice in Bangladesh. Int. Journal of Agronomy and Agricultural Research. 2014; 5(3):40-44.
3. Biswa M, Sultana P, Hideki S, Nobukazu N. Effects of *Azolla* species on weed emergence in a rice paddy ecosystem. Weed Biology and Management. 2005; 5:176-183.
4. Collings CH, Lyne MP. Microbiological methods. 5th Edition, Butter Worth, London, 1968.
5. CPG. Crop Production Guide. Published by Directorate of Agri. Chennai and TNAU, Coimbatore, India, 2012.
6. Ehsanullah RQ, Kalim M, Rehman A, Iqbal Z, Ghaffar A, Mustafa G. Growth and economic assessment of mulches in aerobic rice (*Oryza sativa* L.). Journal of Agricultural Research. 2014; 52(3):395-405.
7. Forcella F, Arnold RLB, Sanchez R, Ghersa CM. Modeling seedling emergence, Agricultural Outlook. 2000; 270:9-14.
8. Gnanasoundari P, Somasundaram E. Non-chemical weed management in organic rice. African Journal of Agricultural Research. 2014; 9(26):2077-2084.
9. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research (2nd edn.). John Wiley and Sons, New York. 1984, 680.
10. Kenknight G, Muncie JH. Isolation of phytopathogenic actinomycetes. Phytopathology. 1939; 29:1000-1001.
11. Khan MAI, Ueno K, Horimoto S, Komai F, Tanaka K. Evaluation of the use of Rice Bran compost for Eco-friendly weed control in organic Farming Systems. American Journal of Environmental Science. 2007; 3:235-240.
12. Kuk YI, Burgos NR, Talbert RE. Evaluation of rice by-products for weed control. Weed Science. 2000; 49(1):141-147.
13. Madhu M, Nanjappa HV. Crop weeds competition in puddled seeded rice. Indian Journal of Weed Science. 1995; 27(3-4):191-193.
14. Martin JP. Use of acid, rose Bengal and streptomycin in the plate method for estimating soil fungi. Soil Science. 1950; 69:215-233.
15. Mubshar H, Farooq S, Ali S. Plastic mulching improves the water use efficiency and productivity of direct seeded and transplanted fine rice. (In:) Proceedings of 3rd International Conference on ‘Frontiers in Agriculture’. October 3-5, 2012. Dankook International Cooperation on Agriculture, Dankook University, Cheonansi, Republic of Korea. 2012, 44-49.
16. NPOP (National Programme for Organic Production). Organic Certification Area and Production Statistics. hptt://www.npop.com. 2012.
17. Olsen SR, Cole CV, Watanable FS, Dean LA. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circ., 1954, 939.
18. Piper CS. Soil and Plant Analysis. Inter Science Publications. New York, 1966.
19. Ramesh P, Subba Rao A. Organic Farming: Status and Research Achievements, India Institute of Soil Science, Bhopal, India, 2009, 74.
20. Singh S, Ladha JK, Gupta RK, Rao AN, Bhushan L, Sivaprasad B, Singh PP. Evaluation of mulching, Intercropping with *Sesbania* and herbicide use for weed management in dry-seeded rice (*Oryza sativa* L.) Crop Production. 2007; 26:518-524.
21. Standford G, English L. Use of flame photometer in rapid soil tests for K and Ca. Agronomy Journal. 1949; 41:446-447.
22. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. Current Science. 1956; 25:259-260.

23. Young-Feng Yan, Jin-Dong FU, Byun-Woo Lee. Rice bran application under Deep flooding can control weed and increase grain science and organic rice culture. Journal of Crop Science and Biotechnology. 2007; 10(2):79-85.
24. Walkley A, Black CA. An examination of digestion method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science. 1934; 37:29-38.
25. Www.apeda.gov.in/apedawebsite/organic/Organic_Products.htm