



RESEARCH ARTICLE

Effect of Weed Management Practices on Crop Growth, Yield and Economics of Direct Seeded Rice Ecosystems

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ABSTRACT

A field trial was carried out in Central Farm of Agricultural College and Research Institute, Madurai during rabi (late samba), 2018-19 to study the effect of weed management on crop growth, yield and economics of rice under various ecosystems. The experiment was laid out in strip plot design with twenty-eight treatment combinations and replicated thrice. The results revealed that among sowing methods, plant height, LAI, LAD, CGR, DMP and yield were observed higher under wet seeded condition whereas, in weed management practices weed free upto panicle initiation stage and the application of Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS showed higher results. The economic analysis revealed that among the methods of sowing, net income and B:C ratio was found higher in puddled condition. Among various weed management practices, higher net return and B:C ratio was observed with the application of Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS. It was followed by the application of Pendimethalin (2.5 kg a.i. ha⁻¹) + Bispyribac sodium (50 g a.i. ha⁻¹) fb one hand weeding at 45 DAS.

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INTRODUCTION

Rice is the prime cereal that is cultivated in an area of 43.1 million hectares with an annual production of 112.9 million tonnes and productivity of 2.6 tonnes ha⁻¹ (India Stat, 2017-18). Rice is being a semi-aquatic plant, it requires water stagnation for its cultivation and normally it utilizes about 4000-5000 lit of water for the production of one kg of rice (Madhukumar et al., 2013). Rice is normally grown by transplanting seedlings in the puddled field which is highly labour intensive and requires 30 man days ha⁻¹ for random planting (Prasad, 2011). Due to increased water scarcity and labour shortage, there has been a shift from conventional transplanting to direct seeding of rice. Direct seeded rice matures earlier than the transplanted crop, which shows that direct seeded crop did not experience any transplanting shock. In addition to that, direct seeded rice is conducive to mechanization, less methane emission and hence offers an opportunity for farmers to earn from carbon credits than the transplanted system. Aerobic rice is a good alternative of transplanting method in which rice is cultivated under unpuddled and unflooded condition with high external input

aiming for high yield. It accounts for about 40 - 50 per cent of water saving than the transplanted rice (Subramanian et al., 2008). In direct-seeded rice, weeds are the serious threat to crop which compete for nutrients, light, space and moisture throughout the growing season. The risk of yield loss from weeds in direct-seeded rice is greater than transplanted rice. Ramzan (2004) reported that, there is a yield reduction up to 48, 53 and 74% in transplanted, direct seeded flooded and direct seeded aerobic rice, respectively. In many occasions, 100 per cent yield reduction was reported under heavy weed infestation condition (Rao et al., 2007). Hence, in order to increase the productivity of direct seeded rice, an ideal time of weed-free condition and efficient weed management is essential to restrict weeds growth, particularly during the critical growth period could induce essential crop growth dynamics with subsequent yield advantage. Keeping this in view, the present study was carried out to study the effect of weed management practices on crop growth, economics and yield under different rice ecosystems.

MATERIAL AND METHODS

A field experiment was conducted at Central

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Farm of Agricultural College and Research Institute, Madurai during *rabi (late samba)*, 2018-19. The experimental field located at the southern agro-climatic zone of Tamil Nadu with 9°54' N latitude and 78°54' E longitude with an altitude of 147 m above mean sea level. The varieties used for the experiment were ASD 16 and TKM 13. The treated and pre-germinated seeds at the seed rate of 30-40 kg ha⁻¹ with a row spacing of 20 cm was sown by drum seeder under the puddled condition and hand dibbled in aerobic condition. The experiment was laid out in strip plot design with twenty-eight treatment combinations and replicated thrice. Main plot consists of four treatments viz. M₁ – Short duration rice under unpuddled condition (Aerobic), M₂ – Medium duration rice under unpuddled condition (Aerobic), M₃ – Short duration rice under puddled condition (Wet-seeded), M₄ – Medium duration rice under puddled condition (Wet-seeded) and sub plot consists of seven treatments such as S₁ – Weed free upto active tillering (AT) stage, S₂ – Weed free upto panicle initiation (PI) stage, S₃ – Weedy upto active tillering (AT) stage, S₄ – Weedy upto panicle initiation (PI) stage, S₅ – Pendimethalin (2.5 kg a.i. ha⁻¹) *fb* one Hand

weeding at 45 DAS, S₆ – Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) *fb* 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS, S₇ – Pendimethalin (2.5 kg a.i. ha⁻¹) + Bispyribac sodium (50 g a.i. ha⁻¹) *fb* one hand weeding at 45 DAS. The phosphatic fertilizer was applied as basal, nitrogen and potash fertilizers were applied in four equal splits at basal, active tillering, panicle initiation and flowering stages with a recommended dose of 150:50:50 kg of N, P₂O₅, K₂O ha⁻¹. The observations on growth parameters were recorded and LAI, LAD and CGR were worked out. The grain yield was recorded at 14 per cent moisture and straw yield was recorded after sundried and both were expressed in kg ha⁻¹. Data were statistically analyzed as per the procedure laid down by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant height

The data on plant height at various growth stages were given in Table 1. Among the sowing methods, short duration rice variety under puddled condition (M₃) recorded taller plants of 72.8 and 104.2 cm at panicle initiation and flowering stages,

Table 1. Effect of sowing methods and weed management on growth parameters of direct seeded rice

Treatment	Plant height (cm)		Leaf area index		Leaf area duration	
	PI	FL	PI	FL	AT-PI	PI –FL
Main plot: Method of sowing						
M ₁	66.9	101.5	3.5	4.41	42.9	79.1
M ₂	64.1	87.4	3.83	4.66	46.3	84.8
M ₃	72.8	104.2	3.68	4.63	43.9	83.1
M ₄	70.2	92.7	4.05	5.12	49.2	91.7
SEd	1.1	1.9	0.1	0.13	1.18	1.9
CD (p=0.05)	2.6	4.7	0.24	0.31	2.89	4.8
Subplot : Weed management						
S ₁	70.2	105	4.13	5.14	52.3	92.7
S ₂	73.7	110	4.64	5.7	56.2	103.4
S ₃	63.5	97.4	3.52	4.36	37.3	78.8
S ₄	57.6	73.2	1.84	2.4	24.6	42.4
S ₅	67.6	99.8	3.73	4.69	44.7	84.2
S ₆	71.9	107	4.5	5.48	54.8	99.8
S ₇	68.9	103	3.99	5.15	49.2	91.4
SEd	1.9	2.2	0.1	0.14	1.34	2.5
CD (p=0.05)	4	4.8	0.21	0.29	2.93	5.4

Interaction effect was non- significant;

AT- Active tillering, PI- Panicle initiation, FL- Flowering

M₁ – Short duration rice under unpuddled condition (Aerobic)

M₂ – Medium duration rice under unpuddled condition (Aerobic)

M₃ – Short duration rice under puddled condition (Wet-seeded)

M₄ – Medium duration rice under puddled condition (Wet-seeded)

S₁ – Weed free upto active tillering (AT) stage

S₂ – Weed free upto panicle initiation (PI) stage

S₃ – Weedy upto active tillering (AT) stage,

S₄ – Weedy upto panicle initiation (PI) stage

S₅ – Pendimethalin *fb* one Hand weeding @ 45 DAS

S₆ – Bensulfuron methyl + Pretilachlor *fb* 2,4-D + one Hand weeding @ 45 DAS

S₇ – Pendimethalin + Bispyribac sodium *fb* one Hand weeding @ 45 DAS

respectively. This was on par with short duration rice variety in aerobic condition (M_1) at flowering stage alone. The shorter plants of 64.1 and 87.4 cm were noticed in medium duration rice variety under aerobic condition (M_2) at panicle initiation and flowering stages. This might be due to that puddled condition favours effective utilization of nutrients and reduced crop-weed competition may result in increased plant height, which is in accordance with findings of Sangeetha *et al.* (2009).

With regard to weed management practices, taller plants of 73.7 (panicle initiation) and 110 cm (flowering) were observed in weed-free upto panicle initiation stage (S_2) which was statistically on par

with the application of Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS (S_6) during panicle initiation and flowering stages and weed-free upto active tillering stage (S_1) was also statistically on par during panicle initiation stage alone. Comparatively, weedy upto panicle initiation stage (S_4) exhibited shorter plants of 57.6 (panicle initiation) and 73.2 cm (flowering). This was mainly because of maintenance of weed-free condition upto critical period which results in a reduction of crop weed competition and in the weedy plot, plant growth gets inhibited by weeds and ultimately produces shorter plants. This is in accordance with the findings of Hasanuzzaman *et al.* (2009).

Table 2. Effect of sowing methods and weed management on Crop growth rate, Dry matter production and yield of direct seeded rice

Treatment	Crop growth rate		Dry matter production		Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
	(g m ⁻² day ⁻¹)		(kg ha ⁻¹)			
	AT - PI	PI-FL	PI	FL		
Main plot: Method of sowing						
M ₁	14.4	9.71	3419	5639	4449	6682
M ₂	11.6	9.93	3973	6959	4627	7012
M ₃	15.0	11.5	3673	6538	4729	7086
M ₄	14.0	9.80	4322	7270	4748	7288
SEd	0.27	0.23	103	158	72.4	129
CD (p=0.05)	0.66	0.56	252	387	177.2	315
Subplot : Weed management						
S ₁	14.6	11.6	4471	7691	5125	7727
S ₂	21.7	13.7	5648	9385	5588	8813
S ₃	7.16	8.28	1763	4024	4513	6719
S ₄	1.96	3.27	866	1756	1796	2927
S ₅	13.6	9.99	4037	6769	4958	7171
S ₆	21.1	13.8	5528	8929	5325	8166
S ₇	16.1	10.9	4616	7655	5163	7596
SEd	0.3	0.4	119	174	134	232
CD (p=0.05)	0.71	0.8	259	379	292	505

M_1 – Short duration rice under unpuddled condition (Aerobic)
 M_2 – Medium duration rice under unpuddled condition (Aerobic)
 M_3 – Short duration rice under puddled condition (Wet-seeded)
 M_4 – Medium duration rice under puddled condition (Wet-seeded)

S_1 – Weed free upto active tillering (AT) stage ,
 S_2 – Weed free upto panicle initiation (PI) stage
 S_3 – Weedy upto active tillering (AT) stage,
 S_4 – Weedy upto panicle initiation (PI) stage
 S_5 – Pendimethalin fb one Hand weeding @ 45 DAS
 S_6 – Bensulfuron methyl + Pretilachlor fb 2,4-D + one Hand weeding @ 45 DAS
 S_7 – Pendimethalin + Bispyribac sodium fb one Hand weeding @ 45 DAS

Leaf area index (LAI) and Leaf area duration (LAD)

Leaf area index and leaf area duration had gradually increased during various growth stages which were presented in Table 1. Among the sowing methods, higher LAI of 4.05 (panicle initiation), 5.12 (flowering) and higher LAD of 49.2 (active tillering to panicle initiation stage), 91.7 (panicle initiation to flowering stage) were registered in medium duration rice variety under puddled condition, whereas, lower LAI and LAD were noticed in short duration rice variety under aerobic condition in all the three stages. Under puddled condition nutrient uptake by crop was higher due to reduced weed growth than aerobic condition.

High nutrient utilization may result in an enhanced photosynthetic activity which leads to better crop canopy cover and ultimately increases the leaf area index. Similar responses have been observed by Sandhu *et al.* (2012).

Among weed management practices, at panicle initiation stage, weed-free upto panicle initiation stage registered higher leaf area index (4.64) which was at par with Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS (4.50) and the lower LAI was recorded at weedy upto panicle initiation stage (1.84). At flowering stage, weed-free upto panicle initiation stage registered higher leaf area index (5.70) which was at par with Bensulfuron

methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS (5.48) and the lower LAI was recorded at weedy upto panicle initiation stage (2.40). Riaz *et al.* (2018) reported that weed free conditions may promote better light interception which enhances the photosynthates accumulation and finally produces higher LAI.

During active tillering - panicle initiation stage, higher LAD (56.2) was recorded in weed-free upto panicle initiation stage which was at par with Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS (54.8). The lower LAD was recorded at weedy upto panicle initiation stage (24.6). Whereas, panicle initiation to the flowering stage also follows the same trend with 45 per cent increase in LAD under weed-free condition and 41 per cent under weedy condition. It might be due to better source-sink relationship in weed-free conditions which is in line with the findings of Muhammad *et al.* (2016).

Crop Growth Rate (CGR)

The data on CGR gradually decreased from active tillering to harvest stage which was given in Table 2. Among the method of sowing with short and medium duration rice varieties, CGR was high in short duration rice variety. However, sowing method does not show significant variations during active tillering to the panicle initiation stage. During panicle initiation to flowering stage, higher CGR (11.5) was registered in short duration rice variety under puddled condition, whereas from flowering to harvest stage, the higher CGR (7.54) was noticed in medium duration rice variety under puddled condition. Crop growth rate decreases with increase in duration. This is in line with the findings of Parthipan (2013). The CGR results clearly indicate that both short duration and medium duration rice varieties are suitable for direct seeded condition. Irrespective of the variety, the magnitude of variation

In case of weed management practices, with regard to CGR, during active tillering to panicle initiation and from panicle initiation to flowering, weed-free upto panicle initiation stage and the application of Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS were at par with each other. CGR was recorded lesser in weedy upto panicle initiation stage during all the stages. Weedy plot results in lesser biomass accumulation which leads to lesser CGR (Singh *et al.*, 2012).

Dry Matter Production (DMP)

Sowing methods had a significant influence on the DMP of rice at all the growth stages as depicted in Table 2. Higher DMP of 4322 and 7270 kg ha⁻¹ was noticed in medium duration rice variety in the puddled condition during panicle initiation and flowering stage, respectively. This was comparable with similar rice variety under aerobic condition at flowering stage. Whereas least DMP of 3419 (panicle initiation) and 5639 kg ha⁻¹ (flowering) was noticed in short duration rice variety under aerobic condition (M₁). This might be due to increased leaf area index under the puddled condition which promotes better source sink relationship results in higher dry matter accumulation.

With regard to different weed management practices, at panicle initiation stage, higher DMP of 5648 kg ha⁻¹ was noticed in weed free upto panicle initiation stage (S₂) and this was statistically on par with the combination of Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS. Whereas at the flowering stage, weed-free upto panicle initiation stage (S₂) alone registered higher DMP of 9385 kg ha⁻¹. This might be due to the effective utilization of available inputs under weed free condition produces higher leaf area, taller plants and more tillers/m² which gave distinctly higher DMP at all the crop growth stages. This is in consistent with the findings of Kumar *et al.* (2017). Lesser DMP of 866 (panicle initiation) and 1756 (flowering) kg ha⁻¹ was noticed in weedy upto panicle initiation stage (S₄).

Sowing methods and weed management on grain and straw yield

The data on grain yield and straw yield are furnished in Table 2. Among sowing methods, higher grain yield of 4748 kg ha⁻¹ and straw yield of 7288 kg ha⁻¹ were recorded in medium duration rice variety under the puddled condition and lesser grain yield of 4449 kg ha⁻¹ and straw yield of 6682 kg ha⁻¹ were recorded in short duration rice variety under unpuddled condition. In comparison with the puddled condition, aerobic condition registered only 6 and 9 per cent reduced grain yield and straw yield, respectively. This might be due to in wet seeded

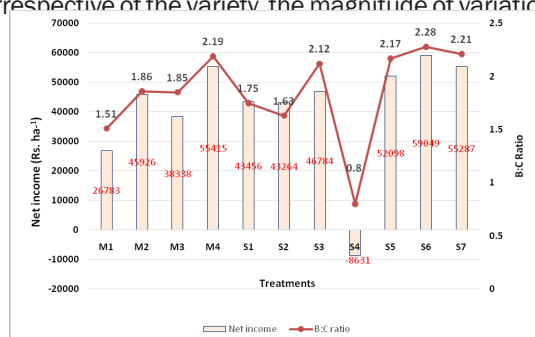


Figure 1. Economic analysis of Net income (Rs. ha⁻¹) and B:C ratio of sowing methods and weed management practices

in between puddled and unpuddled condition was only meager with respect to the crop growth rate.

condition, puddling reduces the weed density and ponding water will suppress the grassy weeds and many sedges at initial stages leads to higher yield when compared to aerobic cultivation. This is in accordance with the findings of Azmi and Johnson (2009). However, the grain yield variation was only 6 per cent hence aerobic rice can be recommended under unpuddled conditions with both short and medium duration rice varieties under water scarce condition.

Among the weed management practices, weed free upto panicle initiation stage recorded higher grain yield of 5588 kg ha⁻¹ and straw yield of 8813 kg ha⁻¹. Comparatively, Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS recorded the grain yield of 5325 kg ha⁻¹ and straw yield of 8166 kg ha⁻¹. This might be due to weed-free upto the critical stages promote better crop growth by limiting crop weed competition whereas weedy upto panicle initiation stage recorded lesser grain yield of 1796 kg ha⁻¹ and straw yield of 2927 kg ha⁻¹. Weedy condition upto panicle initiation stage causes 68 and 66 per cent lesser grain and straw yield, respectively when compared to weed-free condition. This is due to that the weedy conditions increases the crop competition for nutrient uptake, water and solar energy. However poor competitive ability of rice with weeds ultimately causes maximum yield loss as reported by Chauhan *et al.* (2015). The crop-weed competition beyond 15 DAS in direct seeded rice results in significant yield reduction (Singh *et al.*, 2005).

Economic analysis of sowing methods and weed management practices

The data on economic analysis of sowing methods and weed management practices was depicted in Fig.1. Among the method of sowing under puddled and unpuddled (Aerobic) conditions, higher net income of Rs. 55415 ha⁻¹ was found in medium duration rice variety under puddled condition followed by medium duration rice variety under the aerobic condition of Rs. 45926 ha⁻¹. Medium duration rice variety grown under the puddled condition had recorded higher B:C ratio of 2.19 followed by medium duration rice variety under the aerobic condition of 1.86. It might be due to increased duration with fine seeded nature of the variety. The results revealed that the fine seeded medium duration variety performs well in both puddled and unpuddled condition.

Among the weed management practices, higher net income of Rs. 59049 ha⁻¹ and B: C ratio of 2.28 was noticed in Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) fb 2,4-D (1.25 kg a.i. ha⁻¹) + one hand weeding at 45 DAS. It was followed by Pendimethalin (2.5 kg a.i. ha⁻¹) + Bispyribac sodium (50 g a.i. ha⁻¹) fb one hand weeding at 45 DAS has

recorded the net income of Rs. 55287 ha⁻¹ and B: C ratio of 2.21. The results revealed that the combination of pre-emergence and post emergence herbicides along with one hand weeding at 45 DAS was found to be the most cost-effective method of weed management in direct seeded rice. Pre-emergence application of herbicides will maintain weed-free condition upto 15 DAS, post-emergence herbicides may maintain weed-free condition upto 35 DAS and the weeds emerged at the later stage was removed by hand weeding at 45 DAS. Such a combined action of herbicides along with hand weeding helps to maintain weed-free condition upto the critical stage and also reduces the cost of cultivation. Similar results were given by Madhukumar *et al.* (2013).

CONCLUSION

From the above results, it can be concluded that direct seeding under puddled condition was highly suitable for high water resource areas. However, sowing under aerobic condition will also provide similar results if it is maintained in weed-free condition up to the critical stages. Maintenance of weed-free condition by hand weeding during the early stage is very difficult for the farmers due to the increasing labour shortage. Hence the combination of pre-emergence (Bensulfuron methyl (0.6%) + Pretilachlor (6% GR) (10 kg ha⁻¹) and post emergence (2,4-D-1.25 kg a.i. ha⁻¹) herbicides along with one hand weeding at 45 DAS as ideal combination for reducing weed menace at critical stages and to obtain higher yield and economic returns.

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