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Economic feasibility of tillage and herbicide-based weed management practices in dry direct seeded rice

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Abstract

A field experiment was conducted during the *kharif* season at the Agricultural Farm of Palli Siksha Bhavana, Visva-Bharati, Sriniketan, Birbhum, West Bengal, to evaluate the economic feasibility of tillage and herbicide-based weed management practices in dry direct-seeded rice. The experiment was laid out in a split-plot design with three replications. Two tillage practices, viz., zero tillage and conventional tillage, were assigned to the main plots, while eight weed management practices were assigned to the sub-plots. The weed management treatments included sole and sequential herbicide applications, weed-free check and unweeded control. Economic analysis was carried out in terms of cost of cultivation, gross return, net return and return per rupee invested. Results revealed that zero tillage recorded a lower cultivation cost than conventional tillage by 5.67 per cent. However, gross return, net return and return per rupee invested did not differ significantly between tillage practices. Among weed management practices, oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron recorded the highest net return of ₹38,317 ha⁻¹ and return per rupee invested of 1.99. It was closely followed by oxadiargyl followed by penoxsulam + cyhalofop-butyl, which recorded net return of ₹34,674 ha⁻¹ and return per rupee invested of 1.88. The unweeded control recorded the lowest economic return and resulted in a net loss of ₹13,322 ha⁻¹ due to severe weed competition. The study indicated that sequential application of pre-emergence oxadiargyl followed by suitable post-emergence herbicide combinations is economically viable for dry direct-seeded rice under lateritic soil conditions of eastern India.

Keywords: Direct seeded rice, economics, herbicide, net return, oxadiargyl, return per rupee invested, weed management, zero tillage

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops and a staple food for more than half of the world's population. In India, rice is highly important for food security and rural livelihood. Traditionally, rice is cultivated by transplanting seedlings into puddled soil. Though puddling helps in crop establishment and weed suppression, it requires more water, labour and energy. Due to increasing labour shortage, rising cultivation cost and limited irrigation water, transplanted rice is becoming less economical.

Dry direct seeded rice (DSR) is a promising alternative because seeds are sown directly in the field without nursery raising, puddling and transplanting. It reduces labour requirement, saves irrigation water, lowers production cost and allows timely sowing. Direct seeded rice can save labour and irrigation water compared to transplanted rice (Pandey and Velasco, 2002; Pathak *et al.*, 2013) [9, 11].

However, weed infestation is a major problem in DSR because rice and weeds emerge at the same time. Weeds compete with rice for nutrients, moisture, light and space, causing poor crop growth and yield reduction. Yield losses due to weeds in direct seeded rice may range from 20 to 85 per cent in India (Duary *et al.*, 2015) [5]. Therefore, effective weed management is essential for improving yield and profitability.

Manual weeding is effective but costly and labour-intensive. Hence, herbicide-based weed management is a practical option. Pre-emergence herbicides control early weeds, while post-emergence herbicides control later weeds. Sequential herbicide application improves weed control, yield and profitability in DSR.

Materials and Methods

The field experiment was conducted during kharif 2021 at the Agricultural Farm of the Institute of Agriculture, Palli Siksha Bhavana, Visva-Bharati, Sriniketan, Birbhum, West Bengal. The experimental site is located in the lateritic belt of eastern India. The experiment was carried out to study the effect of tillage and weed management practices on dry direct seeded rice. The experiment was laid out in split plot design with three replications. Two tillage practices were assigned to main plots:

- **T₁:** Zero tillage
- **T₂:** Conventional tillage

Eight weed management practices were assigned to sub-plots

- **W₁:** Oxadiargyl 90 g ha⁻¹ followed by bispyribac-sodium 25 g ha⁻¹
- **W₂:** Penoxsulam + cyhalofop-butyl 180 g ha⁻¹
- **W₃:** Oxadiargyl 90 g ha⁻¹ followed by penoxsulam + cyhalofop-butyl 180 g ha⁻¹
- **W₄:** Fenoxaprop-p-ethyl + ethoxysulfuron 90 + 15 g ha⁻¹
- **W₅:** Oxadiargyl 90 g ha⁻¹ followed by fenoxaprop-p-ethyl + ethoxysulfuron 90 + 15 g ha⁻¹
- **W₆:** Pendimethalin 1000 g ha⁻¹ followed by bispyribac-sodium 25 g ha⁻¹
- **W₇:** Weed free check
- **W₈:** Unweeded control

The economics of DSR cultivation was worked out by calculating cost of cultivation, gross return, net return and return per rupee invested. Gross return was calculated based on economic yield and prevailing market price. Net return was calculated by subtracting cost of cultivation from gross return. Return per rupee invested was calculated by dividing gross return by cost of cultivation.

Results and Discussion

Effect of tillage practices on cost of cultivation

The cost of cultivation was lower under zero tillage than conventional tillage. Zero tillage recorded a cost of cultivation of ₹38,616 ha⁻¹, whereas conventional tillage recorded ₹40,939 ha⁻¹. Thus, zero tillage reduced cultivation costs by 5.67 per cent compared to conventional tillage. The main reason for lower cost under zero tillage was saving in land preparation operations, fuel, labour and machinery use. Since zero tillage avoids repeated ploughing and field preparation, it naturally reduces the expenditure on tillage operations.

This result is in agreement with earlier findings that zero tillage can reduce production cost and improve economic returns by saving labour and field preparation expenses. Dash *et al.* (2020) [3] also reported that zero tillage helped in saving labour and production expenditure, thereby increasing net economic returns. Similarly, Prasath *et al.* (2020) [12] reported better gross return, net income and benefit-cost ratio under zero tillage with suitable crop and weed management practices. In the present study also, zero tillage reduced the cost of cultivation without causing significant reduction in gross return, net return or return per rupee invested.

Effect of tillage practices on gross return, net return and return per rupee invested

Tillage practices did not significantly influence gross return, net return and return per rupee invested. Conventional tillage recorded slightly higher gross return of ₹55,804 ha⁻¹ compared to ₹54,209 ha⁻¹ under zero tillage. This may be due to slightly higher grain yield under conventional tillage. The thesis reported

that conventional tillage produced 1.82 per cent higher grain yield than zero tillage, although the difference was statistically non-significant.

However, zero tillage recorded slightly higher net return of ₹15,593 ha⁻¹ compared to ₹14,865 ha⁻¹ under conventional tillage. This was because the lower cost of cultivation under zero tillage compensated for the slightly lower gross return. Return per rupee invested was also marginally higher under zero tillage with 1.38 compared to 1.35 under conventional tillage. Therefore, zero tillage can be considered economically comparable to conventional tillage in dry direct seeded rice.

The non-significant difference between tillage practices may be due to similar crop growth and yield performance under both systems. The thesis also reported that tillage practices did not significantly affect yield attributes and grain yield of DSR. Similar findings were earlier reported by Bhattacharyya *et al.* (2008) [2], who observed that conventional and zero tillage systems produced statistically comparable grain yield in rice.

Effect of weed management practices on cost of cultivation

Weed management practices showed considerable variation in cost of cultivation. The highest cost of cultivation was recorded under weed free check with ₹55,048 ha⁻¹. This was mainly due to repeated manual weeding operations, which increased labour cost. Manual weeding is effective in reducing weeds, but it becomes costly because of high labour requirement, especially during peak crop growth stages.

Among herbicide treatments, oxadiargyl followed by penoxsulam + cyhalofop-butyl recorded a cost of ₹39,536 ha⁻¹, while oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron recorded ₹38,902 ha⁻¹. The lowest cost of cultivation was recorded in unweeded control with ₹33,448 ha⁻¹ because no expenditure was incurred on weed control. However, lower cost alone did not result in higher profitability, because unweeded control suffered severe yield loss due to uncontrolled weed growth.

This clearly shows that cost of cultivation should not be considered alone for judging the best treatment. A treatment may have low cost but may also produce very low yield and poor returns. Therefore, net return and return per rupee invested are more reliable indicators of economic feasibility. The thesis economics table showed that although unweeded control had the lowest cost, it recorded the lowest gross return, negative net return and lowest return per rupee invested.

Effect of weed management practices on gross return

Gross return was significantly influenced by weed management practices. The highest gross return was recorded with oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron, which produced ₹77,219 ha⁻¹. It was followed by weed free check with ₹74,625 ha⁻¹ and oxadiargyl followed by penoxsulam + cyhalofop-butyl with ₹74,210 ha⁻¹. These treatments were statistically at par.

The higher gross return under these treatments was mainly due to higher grain and straw yield. Oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron recorded the highest grain yield of 3636 kg ha⁻¹, which was at par with oxadiargyl followed by penoxsulam + cyhalofop-butyl with 3483 kg ha⁻¹ and weed free check with 3526 kg ha⁻¹. The same treatment also recorded higher straw yield.

The reason for higher yield and gross return was effective control of mixed weed flora. Pre-emergence oxadiargyl controlled the initial flush of weeds, while post-emergence herbicides controlled later emerging weeds. This reduced crop-

weed competition during critical growth stages and improved yield attributes. The thesis reported that sequential application of pre-emergence herbicide followed by post-emergence herbicide effectively controlled mixed weed flora and resulted in higher yield attributes and yield of DSR. These findings are supported by Pratap *et al.* (2017) ^[13], Dhanapal *et al.* (2018) ^[4], Patel *et al.* (2018) ^[10] and Saravanane *et al.* (2020) ^[14].

In contrast, unweeded control recorded the lowest gross return of ₹20,125 ha⁻¹ due to severe weed competition. Weeds compete with rice plants for nutrients, water, light, space and carbon dioxide, which reduces tillering, grain filling and final yield. The thesis reported that uncontrolled weed growth reduced grain yield of DSR by 74.97 per cent.

Effect of weed management practices on net return

Net return is one of the most important indicators of profitability because it shows actual income after deducting the cost of cultivation. Among all weed management practices, oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron recorded the highest net return of ₹38,317 ha⁻¹. It was followed by oxadiargyl followed by penoxsulam + cyhalofop-butyl with ₹34,674 ha⁻¹. These two treatments were economically superior because they produced higher yield with moderate cost of cultivation.

Although weed free check recorded high gross return, its net return was only ₹19,578 ha⁻¹ because of very high cost of cultivation. This indicates that manual weed-free maintenance may increase yield, but the high labour cost reduces profitability. Therefore, herbicide-based sequential weed management was more economical than maintaining a weed free condition manually.

Penoxsulam + cyhalofop-butyl alone recorded a net loss of ₹6,078 ha⁻¹, while unweeded control recorded a net loss of ₹13,322 ha⁻¹. The negative return in these treatments was due to heavy weed pressure and poor yield. The thesis also reported that heavy weed pressure in unweeded control and penoxsulam + cyhalofop-butyl treatment caused negative returns. Nagarjun *et al.* (2019) ^[8] also reported negative net return in weedy plots. The better net return under sequential herbicide treatments can

be explained by their ability to manage weeds during both early and later crop growth stages. Sole post-emergence herbicide application may fail to control early weed flushes, allowing weeds to compete with the crop during the critical period. On the other hand, sequential herbicide application provides broader and longer weed control. This leads to higher crop growth, better yield attributes, higher grain yield and ultimately higher net return.

Effect of weed management practices on return per rupee invested

Return per rupee invested was significantly influenced by weed management practices. The highest return per rupee invested was recorded with oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron with 1.99. It was followed by oxadiargyl followed by penoxsulam + cyhalofop-butyl with 1.88 and oxadiargyl followed by bispyribac-sodium with 1.55.

The high return per rupee invested under oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron was due to the best balance between cost and return. This treatment required moderate investment but produced the highest gross and net returns. Therefore, it was the most economically efficient treatment.

Weed free check recorded return per rupee invested of only 1.36 despite high yield because of high cost of cultivation. This shows that higher yield alone does not guarantee higher profitability. Profitability depends on the relationship between yield, market return and cost of cultivation. Abbas *et al.* (2019) ^[1] also reported that weed free treatment under zero tillage recorded high benefit-cost ratio, but some partially weedy treatments recorded negative net returns and BCR values below one due to poor weed control.

The lowest return per rupee invested was observed in unweeded control with 0.60, followed by penoxsulam + cyhalofop-butyl alone with 0.84. Since both values were below 1.00, these treatments were economically non-profitable. A return per rupee invested below 1.00 means that the farmer is not recovering the cost of cultivation. Therefore, these treatments are not advisable for dry direct seeded rice.

Table 1: Economics of dry direct seeded rice as influenced by tillage practices

Tillage practice	Cost of cultivation ₹ ha ⁻¹	Gross return ₹ ha ⁻¹	Net return ₹ ha ⁻¹	Return ₹ ⁻¹ invested
Zero tillage	38,616	54,209	15,593	1.38
Conventional tillage	40,939	55,804	14,865	1.35
S.Em ±	-	546	546	0.01
LSD P=0.05	-	NS	NS	NS

Table 2: Economics of dry direct seeded rice as influenced by weed management practices

Weed management practice	Cost of cultivation ₹ ha ⁻¹	Gross return ₹ ha ⁻¹	Net return ₹ ha ⁻¹	Return ₹ ⁻¹ invested
Oxadiargyl fb bispyribac-sodium	37,507	57,957	20,450	1.55
Penoxsulam + cyhalofop-butyl	38,044	31,966	-6,078	0.84
Oxadiargyl fb penoxsulam + cyhalofop-butyl	39,536	74,210	34,674	1.88
Fenoxaprop-p-ethyl + ethoxysulfuron	37,410	53,625	16,215	1.43
Oxadiargyl fb fenoxaprop-p-ethyl + ethoxysulfuron	38,902	77,219	38,317	1.99
Pendimethalin fb bispyribac-sodium	38,327	50,327	12,000	1.32
Weed free check	55,048	74,625	19,578	1.36
Unweeded control	33,448	20,125	-13,322	0.60
S.Em ±	-	2343	2343	0.06
LSD P=0.05	-	6786	6786	0.18

Conclusion

The study clearly demonstrated that tillage practices did not significantly influence gross return, net return and return per rupee invested in dry direct seeded rice. However, zero tillage reduced the cost of cultivation by 5.67 per cent compared to

conventional tillage. Therefore, zero tillage may be considered a cost-saving and economically comparable option for dry direct seeded rice.

Among weed management practices, sequential application of oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron

was the most profitable treatment, recording the highest net return of ₹38,317 ha⁻¹ and return per rupee invested of 1.99. It was closely followed by oxadiargyl followed by penoxsulam + cyhalofop-butyl, which recorded net return of ₹34,674 ha⁻¹ and return per rupee invested of 1.88. These treatments were superior because pre-emergence oxadiargyl controlled the initial weed flush, while post-emergence herbicides controlled later emerging weeds, resulting in better weed control, higher yield and greater profitability.

Although weed free check produced high gross return, its net return and return per rupee invested were lower than the best herbicide treatments because of high labour cost. Unweeded control resulted in heavy economic loss due to severe weed competition. Thus, zero or conventional tillage combined with sequential application of oxadiargyl followed by fenoxaprop-p-ethyl + ethoxysulfuron or oxadiargyl followed by penoxsulam + cyhalofop-butyl can be recommended for higher profitability of dry direct seeded rice under lateritic soil conditions of eastern India.

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