**Effect of tillage operation on the productivity and profitability of rice cultivation**

# ABSTRACT

Tillage practices significantly impact rice cultivation by affecting soil properties, which in turn influence crop productivity and profitability. A field experiment was conducted during T. Aman 2016 and Boro 2016-2017 seasons in three fields at Bangladesh Rice Research Institute, Gazipur, aiming to evaluate the effect of different tillage practices on productivity and profitability of rice. In each location the treatments were non-replicated i.e. full set of treatments were replicated in three locations called dispersed replication. The T. Aman and Boro seasons saw the use of the BRRI dhan49 and BRRI dhan29 varieties, respectively. No matter the season, the unit plot size was 25 m x 10 m. In general, regardless of treatment, more labor is needed during the Boro season since it takes longer to uproot and transplant shorter seedlings than during the T. Aman season. Herbicide application, one ploughing, and laddering (T2) took the least amount of labor in both seasons. There was no discernible difference in grain yield across treatments, regardless of season. The greater cost of labor, fertilizer, and irrigation during the Boro season resulted in a higher total variable cost. In both the seasons the highest gross margin was obtained from herbicide application followed by one ploughing and ladderingtreatment hence the cost of per kg of rice was lowest in herbicide application followed by one ploughing and laddering treatment. It was TK. 26.60 and TK. 25.65 in Aman and Boro season respectively. Irrespective of treatments, the BCR was higher in Boro season than T. Aman. For land preparation, four to five ploughings followed by laddering were not necessary in Bangladesh's clay loam soils. One plowing followed by hand grass removal and laddering or herbicide application followed by one plowing and laddering are two methods of preparing land.

*Keywords: Rice, Tillage, Productivity, Profitability,* *soil* *development,* *crop production*

# 1. INTRODUCTION

In Bangladesh, the healthy and sustainable development of soil is affected by agricultural tillage, planting, management practices, and other activities. The main characteristic of the soil in Bangladesh's Agro-Ecological Zone-28 (Madhupur tract) is clay soil or clay loam soil. If this soil is cultivated too much at once, the soil structure breaks down and the plough pan is damaged which causes difficulties in mechanical cultivation and sometimes leads to breakdown of agricultural machinery. By cultivating and hoeing these lands once, instead of using multiple tillage and ladders, the fertility and productivity of the land are increased, as well as the development of the land's plough pan and microbial activity, and at the same time, labor and crop production costs are reduced.

The purpose of soil tillage practice is to improve soil physico-chemical properties and performance through mechanical and other human activities, and coordinate conditions such as soil water storage and fertilizer retention, so as to create suitable soil ecological conditions for plant growth and development [1,2,3]. Bangladesh, as in much of South Asia, most field crops are planted after removal of crop residues from the fields followed by intensive tillage. Intensive tillage degrades soil structure, leads to rapid oxidation of soil organic matter (SOM), increases labour and fuel requirements and overall production cost, and increases greenhouse gas emissions [4]. It also delays establishment of crops, leading to reduced yield and income [4,5]. At the same time, in South Asia and particularly in Bangladesh, more food needs to be produced on less land, using less labour and water. Further, there is a growing concern regarding labor scarcity for agriculture due to migration from rural to urban areas within and outside the countries [6]. The conservation tillage measures represented by no-tillage, improve the soil's water supply and fertilizer supply capacity, and promote crop root growth and nutrient absorption, thereby increasing crop yield and forming suitable soil [7,8,9]. Therefore, finding a suitable tillage management practices have an important role in improving soil structure, promoting crop growth and development, and ensuring stable and high yields and profitability of rice production.

**2. MATERIALS AND METHODS**

**2.1 Study area and soil**

The experiment was conducted from T. Aman (wet season) 2016 to Boro (dry season) 2017 at the season to experimental field of Bangladesh Rice Research Institute, Gazipur, located at 23.58oN latitude and 90.25oE longitude at an elevation of about 8.5 m above the sea level and it's characterized by sub-tropical climate. The location was under the agro-ecological Zone at Madhupur tract (AEZ 28). The soil of fields was clay loam of shallow brown terrace. The field was medium high land with low organic matter content and slightly acidic in reaction having pH value of below 7.

**2.2 Soil sample collection and analysis**

Soil sample collected from 0 to 20 cm soil depths initially and finally after harvest of T. Aman 2016 to Boro 2017 from each plot. The soil samples wer air-dried, ground, passed through a 2-mm sieve, and stored in room-temperature polythene bags for laboratory analysis. The texture, pH, organic matter, total nitrogen, available phosphorus, potassium, and sulphur of initial and post-harvest soil were investigated (Table 1).

**Table 1. The initial and final physical and chemical properties of the soil of the experimental plot BRRI Farm, Gazipur, Bangladesh.**

|  |  |  |  |
| --- | --- | --- | --- |
| Analyses | Initial value | Final value (after harvest) | Method |
| Soil texture | Clay loam | Clay loam | Hydrometer |
| Clay (%) | 43 | 41 |  |
| Silt (%) | 37 | 38 |  |
| Sand (%) | 20 | 22 |  |
| Organic carbon (%) | 1.31 | 1.39 | Walkley-Black |
| Organic matter (%) | 1.56 | 1.71 |  |
| pH (1:1 soil: water) | 6.73 | 6.91 | Potentiometric |
| Total N (%) | 0.11 | 0.15 | Micro-Kjeldahl |
| Available P (ppm) | 5.04 | 5.96 | Modified Olsen's |
| Exchangeable K (meq/100 g soil) | 0.23 | 0.24 | Flam photometer |
| Available S (ppm) | 33.9 | 35.2 |  |
| Available Mn (ppm) | 78 | 81 |  |
| Available Zn (ppm) | 4.0 | 4.01 |  |
| Available Cu (ppm) | 5.18 | 5.18 |  |
| Available Ca (ppm) | 5.0 | 5.0 |  |
| Available Mg (ppm) | 0.18 | 0.18 |  |
| Available Fe (ppm) | 84 | 84 |  |

Source: BRRI Soil Science Division, Gazipur, Bangladesh

**2.3. Climatic condition of the experimental area**

The area is situated under subtropical Zone which was characterized high temperature and high humidity. During T. Aman season there is sufficient rainfall for growing the crops. But the Boro season rainfall was limited and irrigation water was given as and when necessary. The bright sunshine hours were high in the season compared to the T. Aman season. The average annual rainfall is 77.45 mm, of which 70% occurs between mid-June to end of September. The lowest mean temperature (170 C) prevails in January and the highest (350 C) in May.

**2.4. Treatments and Experimental Design**

The treatments were- T1 = Normal cultivation practices i.e. four ploughing followed by laddering, T2 = Herbicide application followed by one ploughing and laddering and; T3 = One poughing then removal of grass by hand followed by laddering. In our experiment, the three replications were implemented at three different locations within the BRRI farm. At each locations, the full set of three treatments (T1, T2, and T3 ) was applied once, meaning that each treatment was replicated only once per site. This design resulted in a total of three replications per treatment, with the replications being spatially dispersed. This approach is referred as dispersed replications, where the complete set of treatments is repeated across different physical locations to capture the natural variability in field conditions. Although the replications were not situated within a uniform block, each location contained all treatments. Therefore, for statistical purposes, the locations were treated as blocks, and the data were analyzed using the Randomized Complete Block Design framework. The variety BRRI dhan49 and BRRI dhan29 were used in T. Aman and Boro season respectively. The unit plot size 25 × 10 m irrespective of season. Labour requirements for different operations such as land preparation, seedling uprooting, transplanting, weeding, harvesting, threshing and winnowing were done through direct supervision.

**2.5 Statistical Analysis**

**Collected data were statistically analyzed using a standard procedure (Statistix 10)**

**3. RESULTS AND DISCUSSION**

The labour requirement in rice cultivation varies significantly between seasons and cultivation methods. Observed data in T. Aman (249-266 man-days ha-1) and in Boro (265-282 man-days ha-1), align with established findings on labour demands. Rice cultivation in Bangladesh remains highly labor-intensive, especially during transplanting and harvesting. Islam *et al.* (2016) demonstrated that traditional manual transplanting in Bangladesh requires 123-150 man-hours ha-1, substantially increasing labour inputs during both T. Aman and Boro seasons [10]. In contrast, mechanical transplanting using 4-row walking-type transplanters reduced labour needs dramatically to approximately 9.0-10.5 man-hours ha-1, illustrating a marked efficiency gain. Ali *et al.* (2019) found that Boro rice cultivation in the haor area required about 149 man-days ha-1, with higher inputs in areas access to mechanized transplanting or harvesting [11]. Rahaman *et al.* (2022) showed that in Sylhet, Boro rice production involved significant hired labour, especially for transplating and harveting, aligning with your Boro season data (265-282 man-days ha-1) [12]. In this study, the labour requirement from seed bed preparation to harvesting in T1, T2 and T3 tratments was 266, 249 and 264 md ha-1, respectively in T. Aman season. But in Boro season it was 282, 265 and 280 md ha-1 in T1, T2 and T3, respectively (Table 2).

The cost of cultivation for land preparation in T. Aman season was Tk. 6500, 2600 and 5800 in T1, T2 and T3 treatment, respectively (Table 3). Land preparation costs vary depending on the number of tillage passes, the use of power tillers or tractors, and field conditions. Islam *et al.* (2017) demonstrated that land preparation using two-wheel tractors reduced costs to Tk.2,500-3,500 per hectare, consistent with T2 (Tk. 2,600) treatment [13]. Thomson & Miah (2018) obseved that non-puddled transplanting with mechanical methods significantly reduced land preparation costs and increased efficiency compared to conventional puddled system, which could explain the higher costs in T1  (Tk. 6,500) and T3 (Tk. 5,800) [14]. Hossain & Dey (2014) emphasized that over 90% of land preparation is now mechanized in Bangladesh, but adoption rates vary by region and farm size [15].

**Table 2. Labor requirement (md ha-1) for different operation of rice cultivation in T. Aman 2016 and Boro 2016-17 seasons.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | Seed bed preparation,  seedling  uprooting etc. | | Transplanting | | 1st  weeding | | 2nd  weeding | | Harvesting | | Carrying,  Threshing,  Cleaning and Drying | | Total | |
|  | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro | Aman | Boro |
| T1 | 26a | 28a | 58a | 58a | 40a | 44a | 30a | 34a | 44a | 48a | 68a | 68a | 266a | 282a |
| T2 | 26a | 28a | 58a | 58a | 30b | 34b | 25b | 29b | 44a | 48a | 66a | 66b | 249b | 265c |
| T3 | 26a | 28a | 58a | 58a | 40a | 44a | 30a | 34a | 44a | 48a | 66a | 66b | 264a | 280b |
| LSD (.05) | 3.46 | 2.61 | 2.26 | 2.61 | 2.26 | 1.39 | 2.61 | 1.30 | 2.26 | 3.06 | 2.26 | 1.30 | 2.77 | 1.30 |
| CV(%) | 5.88 | 4.12 | 1.72 | 1.99 | 2.73 | 1.42 | 4.08 | 1.79 | 2.27 | 2.82 | 1.50 | 0.87 | 0.47 | 0.21 |

Labour wage Tk 450 per labour.

**Table 3. Cost (Tk ha-1) of different tillage operation for rice cultivation in T. Aman 2016 and Boro 2016-17 season.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cost item | T. Aman | | | Boro | | |
| T1 | T2 | T3 | T1 | T2 | T3 |
| Land preparation: Diesel, driver, labor and herbicide | 6,500 | 2,600 | 5,800 | 6,500 | 2,600 | 5,800 |
| Labour for different operation | 1,19,700 | 1,12,050 | 1,18,800 | 1,26,900 | 1,19,250 | 1,26,000 |
| Seed | 700 | 700 | 700 | 700 | 700 | 700 |
| Fertilizer | 6,574 | 6,574 | 6,574 | 12,000 | 12,000 | 12,000 |
| Insecticide | 10,000 | 10,000 | 10000 | 10000 | 10000 | 10000 |
| Irrigation | 8,500 | 8,500 | 8,500 | 24,000 | 24,000 | 24,000 |
| Total variable cost (TVC) | 1,51,974 | 1,40,424 | 1,50,374 | 1,80,100 | 1,68,550 | 1,78,500 |

labour wage Tk 450 per labour. Price of rice and straw per kg: Tk 27.5 and Tk 3.0, respectively.

But in Boro season it was same for T1 and T2 treatments but about 12% higher in T3 treatment due to higher number of labour involved for removal of grass. Generally, irrespective of treatment higher number of labour required in Boro season due to more number of labour required for shorter type of seedling uprooting, transplanting (Table 3). Islam *et al*. (2021) reported that transplanting and harvesting together represent around 40% of the total labour cost in Boro rice labour-intensive stages that significantly inflate production expenses -while mechanization in these operations can save about 40 man-days ha-1[16]. Notably, labour wages have risen from BDT 180/day in 2010 BDT 397/day by 2018, underscoring escalating cultivation costs. Ahmed *et al.* (2021) evaluated various integrated weed management (IWM) strategies, including pre- and post-emergence herbicide treatments followed by manual weeding. During the Boro season, labour use in such IWM treatments was 32-45% lower than conventional practices signifying a substantial reduction in labour requirements compared to untreated or manually weeded fields. Bhuiyan, Salam,and Kabir (2020) emphasize the effectiveness of integrated weed management combining herbicide application with one hand weeding or mechanical weeding to sustain rice yield and reduce costs. The found that applying herbicides at the correct stage can cut weeding costs by approximately 61%, and mechanical weeders reduce costs by 50%, boosting gross returns in Aus, T. Aman, and Boro seasons [17]. Tanu, Biswas, Ahmed, and Samanta (2020) evaluated several herbicides such as butachlor, pyrazosulfuron-ethyl, and their integration with sunflower residues in transplanted T. Aman rice. They reported that butachlor achieved the highest gross margin (Tk. 22,955 ha-1) and BCR of 1.32, with yield comparable to manual weeding. Combining residues with pyrazosulfuron was effective and environmentally sustainable, albeit slightly less profitable [18]. Jame *et al.* (2023) similarly found that mixed herbicides like acetochlor + bensulfuron methyl delivered superior weed suppression, highest gross return (Tk. 146,010), net return (Tk. 88,699), and BCR of 2.55 in transplanted Aman rice [19].

In both seasons T2 required the lowest number of labour. In both seasons, total variable cost was the highest in normal cultivation practices followed by removal of grass/straw by hand and lowest in herbicide applied plot (Table 3). Irrespective of season, the grain yield had no significant difference in different treatments. Total variable cost was higher in Boro season due to higher cost of irrigation, fertilizer and laborers. In both the seasons the highest gross margin was obtained from T2 treatment hence the cost of per kg of rice was lowest in T2 treatment. It was TK. 26.60 and TK. 25.65 in Aman and Boro season respectively. Irrespective of treatments, the BCR was higher in Boro season than T. Aman. In T. Aman season, it was 1.08, 1.17 and 1.09 in T1, T2 and T3 treatments respectively. In boro season, it was 1.17, 1.20 and 1.11 in T1, T2 and T3 treatments respectively (Table 4). Partial budgeting showed that in Aman season, application of T2 treatment instead of T1 and T3 TK. 11,330 and 10,560 ha-1, respectively will be more profitable (Table 4. a, b). But in Boro season, application of T2 treatment instead of T1 and T3 TK. 3,330 and 13,700 ha-1, respectively will be more profitable (Table 5. c, d).

**Table 4. Yield, gross return, gross margin, cost of production of per kg rice and BCR for different tillage operation for rice cultivation in Aman 2016 and Boro 2016-17 season.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cost item | T. Aman | | | Boro | | | LSD (.05) | | CV (%) | |
| T1 | T2 | T3 | T1 | T2 | T3 | A | B | A | B |
| Grain yield (t ha-1) | 5.3a | 5.28a | 5.26a | 6.87a | 6.57b | 6.45c | 0.13 | 0.03 | 1.11 | 0.2 |
| Straw yield (t ha-1) | 6.35b | 6.48a | 6.46a | 7.32b | 7.35a | 7.2b | 0.02 | 0.02 | 0.18 | 0.1 |
| Gross return  (Tk ha-1) | 164800a | 164640a | 164030c | 210885a | 202725b | 198975c | 1.30 | 2.61 | 0.00 | 0.0 |
| Total variable cost (Tk ha-1) | 151914a | 140424c | 150374b | 180100a | 168550c | 178500b | 11.55 | 13.08 | 0.00 | 0.0 |
| Gross margin  (Tk ha-1) | 12886c | 24216a | 13656b | 30785b | 34175a | 20475c | 5.23 | 2.61 | 0.01 | 0.0 |
| Cost of production (Tk kg-1 rice) | 28.66a | 26.60c | 28.59b | 26.21b | 25.65c | 27.67a | 0.04 | 0.03 | 0.07 | 0.05 |
| BCR | 1.08b | 1.17a | 1.09b | 1.17b | 1.20b | 1.11c | 0.02 | 0.01 | 0.82 | 0.6 |

Price of rice and straw per kg: Tk 27.5 and Tk 3.0, respectively and A = Aman, B = Boro

**Table 5. Partial budgeting:**

1. T2 versus T1 in T. Aman

|  |  |  |  |
| --- | --- | --- | --- |
| Debit | | Credit | |
| Cost for using T2 | 140,424 | Return from using T2 | 164,640 |
| Revenue forgone for not using T1 | 164,800 | Cost for using T1 | 151,914 |
| Profit/Loss | + 11,330 |  |  |
| Total | 316,554 |  | 316,554 |

1. T2 versus T3 in T. Aman

|  |  |  |  |
| --- | --- | --- | --- |
| Debit | | Credit | |
| Cost for using T2 | 140,424 | Return from using T2 | 164,640 |
| Revenue forgone for not using T3 | 164030 | Cost for using T3 | 150,374 |
| Profit/Loss | + 10,560 |  |  |
| Total | 315,014 |  | 315,014 |

1. T2 versus T1 in Boro

|  |  |  |  |
| --- | --- | --- | --- |
| Debit | | Credit | |
| Cost for using T2 | 168,550 | Return from using T2 | 202725 |
| Revenue forgone for not using T1 | 210885 | Cost for using T1 | 180100 |
| Profit/Loss | + 3,390 |  |  |
| Total | 382,825 |  | 382,825 |

1. T2 versus T3 in Boro

|  |  |  |  |
| --- | --- | --- | --- |
| Debit | | Credit | |
| Cost for using T2 | 168,550 | Return from using T2 | 202725 |
| Revenue forgone for not using T3 | 198975 | Cost for using T3 | 178,500 |
| Profit/Loss | + 13,700 |  |  |
| Total | 381,225 |  | 381,225 |

**4. CONCLUSION**

The experiment results concluded that there is no need to four/five ploughing followed by laddering in land preparation of BRRI Gazipur farm. Land can be prepared as: Option 1: One ploughing followed by removal of grass by hand and laddering or Option 2: Herbicide application followed by one ploughing and laddering is sufficient.

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**REFERENCES**

1. Shi JL, Liu JZ and Wu FQ 2006. Research advances and comments on conservation tillage. Agricul Res·Arid Areas. **24**(1): 205-212.
2. Vita DP, Paolo ED, Fecondo G, Difonzo N and Pisante M 2007. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. Soil Tillage Res, **92**(1/2): 69-78.
3. López-Fando C and Pardo MT 2009. Changes in soil chemical characteristics with different tillage practices in a semi-arid environment[J]. Soil Tillage Res. **104**(2): 278-284.
4. Johansen, C.; Haque, M.E.; Bell, R.W.; Thierfelder, C.; Esdaile, R.J. Conservation agriculture for small holder rainfed farming: Opportunities and constraints of new mechanized seeding systems. Field Crops Res. 2012, 132, 18-32.
5. Gathala, M.K.; Ladha, J.K.; Kumar, V.; Saharawat, Y.S.; Sharma, P.K.; Pathak, H. Tillage and crop establishment affects sustainability of South Asian rice–wheat system. Agronomy J. 2011, 103, 961−971.
6. Mottaleb, K.A.; Krupnik, T.J.; Erenstein, O. Factors associated with small-scale agricultural machinery adoption in Bangladesh: Census findings. J Rural Stud. 2016, 46, 155-158.
7. Blanco-Moure N, Moret-Fernández D and López MV 2012. Dynamics of aggregate destabilization by water in soils under long-term conservation tillage in semiarid Spain. Catena **99**: 34-41.
8. Dairon R, Dutertre A, Tournebize, J, Marks-Perreau J and Carluer, N 2017. Long-term impact of reduced tillage on water and pesticide flow in a drained context. Environ. Sci. Pollut. Res. **24**: 6866-6877.
9. Nunes MR, van Es HM, Schindelbeck R, Ristow AJ and Ryan M 2018. No-till and cropping system diversification improve soil health and crop yield. Geoderma **328**: 30-43.
10. Islam, AKMS,Rahman, MA., Islam, MT., & Rahman, ML. 2016. Techno-economic performance of 4-row self-propelled mechanical rice transplanter at farmers' field in Bangladesh Progressive Agriculture, 27(3), 369-382. https://doi.org/10.3329/pa.v27i3.30834
11. Ali, S., Kashem, A., & Aziz, MA. 2019. Agro-economic performance of Boro rice cultivation at farmers' level of haor area in Bangladesh. International Journal of Agriculture, Environment and Food Sciences, 3(2), 78-82. https://doi.org/10.3105/jaefs.2019.2.5
12. Rahaman, MS., Sarkar,MAR., Rahman,MC., Deb, L., Rashid, MM., Reza, MS., & Siddique, MAB. 2022. Profitability analysis of paddy production in diffrent seasons in Bangladesh: Insights from the Haor region. International Journal of Agricultural and Environmental Food Sciences, 6(3), 327-339.
13. Thomson, J., & Miah, MAM 2018. Transplanting into non-puddled soils with a amall-scale mechanical transplanter reduced fuel, labour, and irrigation water requirements for rice establishment and increased yield. Archives of Agronomy and Soil Science, 64(4), 465-476. <https://doi.org/10.1080/03650340.2017.1356923>
14. Hossain, M., & Dey, NC 2014. Mechanization for sustainable agricultural intensification in Bangladesh: Policy and investment priorities. FAO & CIMMYT Report. https://www.cimmyt.org/funder\_partner/fao/
15. Islam, AKMS 2021. Mechanized cultivation increases labour efficiency. Bangladesh Rice Journal,24(2), 49-66. <https://doi.org/10.3329/brj.v24i2.53448>
16. Ahmed, S., Kumar, V., Alam, M., Dewan, MR., Bhuiyan., KA., Miajy, AA., Shaha, A., Singh, S., Timsina, J, & Krupnik, T.J 2021. Integrated weed management in transplanted rice: options for addressing labor constrains and improving farmers' income in Bangladesh. Weed Technology, 35(5), 1-34. bioone.org+1cambridge.org+1
17. Bhuiyan, MKA., Salam, MU., & Kabir, MS 2021. Integrated weed management strategies for sustainable rice production in Bangladesh. Bangladesh Rice Journak, 24(2), 133-159. https://doi.org/10.3329/brj.v24i2.53454
18. Tanu, SS., Biswas, P., Ahmed, S., & Samanta, SC 2020. Effect of sunflower residues and herbicide on weed suppression, grain yield and economics of transplanted Aman rice. Bangladesh Agronomy Journal, 23(1), 47-58. <https://doi.org/10.3329/baj.v23i1.50116>
19. Jame, ZH., Zahan, T., Hossain, HMMT., Roy, PS., & Masum. SM 2023. Efficacy of herbicide mixtures for transplanted Aman rice in silty clay loam soil of Bangladesh. Bangladesh Agronomy Journal, 26(1), 56-74. https://doi.org/10.3329/baj.v26i1.69759