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Energy utilization in unpuddled transplanting of wet season rice

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Introduction

Energy is the key input in modern agriculture. Productivity of agriculture depends on adequate inputs such as power, improved seeds, fertilizers and irrigation water. One way to optimize energy consumption in agriculture is to use efficient crop production methods (Kitani, 1999). Crop yield is directly linked with energy input (Srivastava, 1982). In a conventional cropping system, the greatest energy consumer is soil tillage. In comparison to conventional cultivation fuel consumption can be reduced by 3 to 4 fold with the no-till system (Moitzi, 2005). Sayre (2000) summarized the potential advantages of reduced tillage planting systems as reduced fossil fuel use; reduced production cost; increased profit; reduced crop turn-around time; increased land-use efficiency; reduced drudgery in planting, especially suitable for female household members; more efficient crop water use (for both rainfed and irrigated conditions); improved soil physical, chemical and biological activities; enhanced carbon sequestration; and enhanced flora and fauna biodiversity. A change in soil tillage method also causes a slow, but substantial modification to the soil physico-chemical characteristics (bulk density, porosity, infiltration, moisture content and temperature), which becomes apparent in the medium to long term. Rice establishment under unpuddle transplanting system is the new phenomenon which was first time evaluated under the project *"Addressing constraints to pulses in cereals-based cropping systems, with particular reference to poverty alleviation in north-western Bangladesh"* during the dry cool boro rice season in 2009 in 8 farmers filed of Rajshahi district. These trials had provided some exciting results on irrigation water saving and reduction of tillage and cost without grain yield penalty. Therefore, the present study was undertaken to compare the operating energy involved in wet season transplanted rice culture under conventional puddling and a range of non-puddled ("unpuddled") systems.

Materials and Methods

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) Regional Station, Rajshahi, in the wet season of 2009. The 2-wheel tractor (2-WT) operated Versatile Multi-Crop Planter –VMP (Islam, 2010) was used for land preparation of all tillage types except the puddled treatments, which involved 2 dry tillage passes followed by additional 2 wet tillage passes using the 2-WT rotary tiller. Tillage treatments were conventional tillage and puddling (CT); puddling and then beds formed manually (BP_1); 58 cm dry bed formed by the VMP in a single pass (BP_2); and dry strip tillage by the VMP in a single pass (ST). Rice seedlings were transplanted under puddle condition in CT and BP_1 and unpuddled condition for BP_2 and ST. A randomized complete block design with three replications was used for this experiment. Thirty five-day-old rice seedlings of BR 11 were transplanted in all treatments by hand. Both direct and indirect energy inputs were estimated (Table 1). The chemical and biological energy inputs were considered as indirect energy inputs, whereas physical energy inputs were allocated across both indirect and direct energy inputs (Singh et al., 1994). The amounts of labor, fuel, fertilizer and pesticides (herbicide, insecticide and fungicide) were recorded and used in the determination of the fertilizer and chemical energy inputs in the crop production process. These amounts were converted to energy input using energy conversion factors from Gopalan et al. 1978; Bala and Hussain,1992; Mandal et al., 2002; Singh, 2002; Canakci et al., 2005; Yilmaz et al., 2005; Erdal et al., 2007; Esengun et al., 2007. Grain and straw yields were converted to energy output using a conversion factor of 14.57 MJ kg^{-1} for grain and 12.5 MJ kg^{-1} for straw (Bala and Hussain, 1992; Ozkan et al., 2004). The energy use was calculated for all operations in the crop production process, namely, (i) seedling raising; (ii) land preparation; (iii) transplanting; (iv) weeding; (v) fertilizer and pesticide application; and (vi) harvesting and threshing.

Results and Discussion

Direct energy consumption accounted for only a small proportion of the total energy consumption, ranging from around 9 % in CT, BP_1 and BP_2 to 4 % in ST (Table 1). Direct energy use was highest in CT and BP_1 (2.35 and 2.41 GJ ha^{-1}) and least in ST (0.78 GJ ha^{-1}). Fuel was the main direct energy input. Human input was low, even with manual bed formation. Indirect energy accounted for 91.2 % of total energy use in CT, 90.8 % in BP_1, 91.3 % in BP_2 and 95.9 % in ST. The largest source of indirect energy consumption was from fertilizer (37 to 52 % of the total energy consumption). The other major forms of energy consumption were in irrigation, machinery (in conventionally tilled systems), and plant protection.

Reduced tillage decreased energy consumption as fuel use by machine. Avoidance of puddling almost halved irrigation energy use in rice production. The operational energy input was highest for the treatments of CT and BP_1 (26 -27 GJ ha^{-1}) and least for BP_2 and ST (19-20 GJ ha^{-1}). Energy savings in BP_2 and ST were 19 and 24 %, respectively, compared to CT, mainly due to low fuel consumption in tillage operation, lesser machinery use and reduced irrigation. Grain yields were statistically similar i.e. 4.43, 4.56, 4.55 and 4.30 t ha^{-1} which was equivalent to energy outputs of 64.52, 66.50, 66.23 and 62.73 GJ ha^{-1} for CT, BP_1, BP_2 and ST, respectively. Table 2 showed that the energy output/input ratio was least in CT and BP_1 (4.6- 4.8) and 40 % higher in BP_2 and ST (6.0-6.5). The results showed that the reduced number of tillage operations resulted in about a 25 % energy saving and a 40 % increase in energy use efficiency, and that the energy consumption for mechanization accounts for less than one fifth of the total balance.

Table 1: Energy consumption (GJ ha^{-1}) based on energy sources under different tillage options

	Conventional tillage and puddling (CT)	Puddling and then beds formed manually (BP_1)	58 cm dry bed formed by the VMP in a single pass (BP_2)	Dry strip tillage by the VMP in a single pass (ST)
Direct energy				
Fuel	2.20 (8.2)	2.24 (8.5)	1.51 (7.5)	0.54 (2.8)
Human	0.16 (0.6)	0.17 (0.6)	0.25 (1.2)	0.25 (1.3)
Subtotal	**2.35 (8.8)**	**2.41 (9.2)**	**1.76 (8.7)**	**0.78 (4.1)**
Indirect energy				
Seed	0.44 (1.6)	0.44 (1.7)	0.44 (2.2)	0.58 (3.0)
Machinery	4.39 (16.4)	3.89 (14.8)	1.01 (5.0)	0.60 (3.1)
Fertilizing	9.93 (37.1)	9.93 (37.8)	9.93 (49.0)	9.93 (52.0)
Plant protection	3.93 (14.7)	3.93 (14.9)	3.93 (19.4)	3.93 (20.6)
Irrigation	5.71 (21.3)	5.71 (21.7)	3.21 (15.8)	3.28 (17.2)
Subtotal	**24.40 (91.2)**	**23.88 (90.8)**	**18.51 (91.3)**	**18.31 (95.9)**
Total	**26.75a (100)**	**26.30a (100)**	**20.27b (100)**	**19.10c (100)**

Figures in the parenthesis indicate the percentage. In a row, means followed by a common letter(s) are not significantly different at 5 % level by LSD test. $LSD_{0.05}$ = 0.73, CV (%) = 1.57

Table 2: Energy input-output relationship under different tillage options

Parameter	**Conventional tillage and puddling (CT)**	**Puddling and then beds formed manually (BP_1)**	**58 cm dry bed formed by the VMP in a single pass (BP_2)**	**Dry strip tillage by the VMP in a single pass (ST)**	**CV, %**	**$LSD_{0.05}$**
	GJ ha^{-1}	**GJ ha^{-1}**	**GJ ha^{-1}**	**GJ ha^{-1}**		
Output (grain + straw)	123.08	125.92	121.80	122.79	8.88	NS
Energy output/input ratio	4.6b	4.8b	6.0a	6.5 a	8.70	0.95

In a row, means followed by a common letter(s) are not significantly different at 5 % level by LSD test.

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