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Unpuddled transplanting: a productive, profitable and energy efficient establishment technique in rice under Eastern sub-Himalayan plains

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ABSTRACT

The study was undertaken in sandy loam soils of Eastern sub-Himalayan plains with the objectives to arrive at optimal tillage requirement in rice to economise on fuel, labour, time and energy and also to judge the performances of different promising varieties of this zone under those alternative crop establishment techniques for getting higher profitability. The experiment was laid out in a split-plot design having 20 treatment combinations in 3 replicates. Four different crop establishment methods viz., direct seeding through zero till drill (DSR), bed planting (BP), unpuddled transplanting (UPTR) and puddled transplanting(PTR) in main plot and five different varieties viz., Swarna sub 1, Pratiksha, IET 5656, Naveen and MTU 7029 in sub plots were allocated randomly. It was revealed that PTR recorded significantly higher grain yield (4502 kg ha^{-1}) in the first year, while UPTR recorded maximum grain yield (4616 kg ha^{-1}) during second year of experimentation, being at par with PTR (4606 kg ha^{-1}). Grain yield varied significantly among the varieties in both the years of experimentation. Swarna Sub 1 (3779 kg ha^{-1}) in first year and Pratiksha (4215 kg ha^{-1}) in second year recorded maximum grain yield. Use of machineries under alternate cop establishment techniques reduced the fuel, labour and time requirement under those alternate crop establishment techniques. The total energy input in rice were reduced to 9269.95, 7865.00 and 7589.30 MJ ha^{-1} under UPTR, BP and DSR, respectively, due to less fuel and labour requirement as compared to PTR(10862.30 MJ ha^{-1}). It was interesting to note that despite higher output energy and net energy gain under PTR, energy efficiency was recorded maximum under UPTR (15.88) reflecting its higher efficiency over other crop establishment techniques. Despite higher gross returns under PTR, UPTR reflected a higher net return in both the years of experimentation. As the yields were similar in PTR and UPTR, reduced cost of cultivation under UPTR resulted in much higher net returns for all the varieties. It can be concluded that unpuddled transplanting in rice would be the most viable option in rice-wheat cropping system in Eastern sub-Himalayan plains in terms of productivity, energy-efficiency as well as profitability.

Key words: *Crop establishment techniques, unpuddled transplanting, energy relations, production economics, productivity*

INTRODUCTION

Rice (*Oryza sativa* L.) based cropping systems are dominating in the Eastern sub-Himalayan plains of the country where rice is an important staple food for poor people. Majority of the fields in this tract is under puddled transplanted (PTR) rice. However, transplanting of rice is becoming increasingly difficult due to the non-availability of labour during peak season and uneconomical due to high labour wages, the rising cost of fuel and decreasing availability of irrigation water. Traditionally rice is grown by manual transplanting of 25-30 days old seedlings after puddling. Again, puddling requires lot of tillage and water (300 mm) and it destroys soil structure, which affects growth and development of succeeding upland crops in the rotation, thereby reducing the system productivity (Hobbs and Gupta, 2003a). Kukal and Aggarwal (2003a) reported that puddling had adverse effects on soil physical conditions due to intensive churning of the soil and it promotes the formation of hard pan at a shallow depth of 15-25 cm and reduces its root growth resulting in poor nutrient and water absorption (Boparai et al., 1992). Puddling takes upto 30% of total irrigation water application in rice in light textured soils (Aslam et al., 2002). It requires nursery raising, its uprooting and supply for transplanting in the field and continuous ponding of water for first 15 days. This leads to nutrient losses through leaching besides causing high evapotranspiration losses during the hotter months. Though puddling has a great impact in controlling weeds and easy transplanting; however, it creates soil physical condition detrimental to the following crop in rice based cropping system (Hobbs and Morris, 1996). The destruction of soil structure and formation of hard pan during puddling may have adverse effects on the growth and yield of subsequent non rice crop in the relation and these crops also require more energy for field preparation (Kumar and Ladha, 2011). Thus the productivity and sustainability of rice-based cropping systems are under threat because of deterioration of soil health due to intensive wet and dry tillage in sequence, scarcity of labour, water and energy, changing climate scenarios and emerging socio-economic changes due to urbanization, migration of labour and less preference of agricultural work due to more drudgery and risk involvement.

The conservation agricultural based new agronomic management practices are addressing the above challenges. Dry direct seeded rice in no-till or till soil is an alternate options for transplanted rice but due to high pre-monsoon shower in this eastern sub-Himalayan plains farmers did not get the appropriate window to adopt the direct seeded rice. Under the circumstances, unpuddled transplanting (UPTR) is a promising alternative option in which similar yields can be achieved with very minimum tillage operations. Islam et al. (2014) reported that in wet season, bed planting and strip tillage under unpuddled condition saved fuel and water usage by 31-76 % and 25-26 % compared to conventional tillage, respectively. Minimum tillage also saved about 30-54% fuel consumption and 40-49% labour requirement compared to conventional tillage in land preparation and labour did not face much difficulty to transplant seedling in unpuddled fields (Islam et al. 2012). Keeping these in mind, the present study was conducted to examine the effect of various alternative crop establishment techniques on productivity, energy efficiency and profitability of rice.

MATERIALS AND METHODS

The experiment was conducted in the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar located at 26°24'02.2"N latitude, 89°23'21.7"E longitude and at an elevation of 43 meters above mean sea level. It was carried out for two consecutive years, *i.e., kharif*, 2015 and 2016. The experimental soil was sandy loam in texture with pH-5.54, Organic C (%) - 0.91, mineralizable N-128.36 kg ha^{-1}, available P -17.5 kg ha^{-1} and available K 122.1 kg ha^{-1}. The experiment was laid out in a split-plot design having 20 treatments in 3 replicates. Four different crop establishment methods *viz.,* direct seeding through zero till drill (DSR), bed planting (BP), unpuddled transplanting (UPTR) and puddled transplanting (PTR) in main plots and five different varieties *viz.,* Swarna sub 1, Pratiksha, IET 5656, Naveen and MTU 7029 in sub plots were allocated randomly. The crop establishment methods were in long narrow strips with a size of each experimental plot of 50 m x 2m.

Direct seeding was performed with National zero till drill (9-tyne). Bed planting was done with 2-wheel drive RWC bed planter. It formed the bed with a single pass over the previous crop stubbles. The beds were loose with a height of only 5-7 cm. It was also basically direct seeding with localised placement of fertilizers as fertilizers were thrown over the rows only during seeding. For UPTR, the land was ploughed once with the power tiller. Land was kept moist through holding water for 3-4 days before ploughing once through power tiller after which the seedlings were transplanted with the help of 8-row transplanter. Seedlings were raised in mat nursery bed as it was pre-requisite for machine transplanting. A mat-type nursery is a nursery where rice seedlings are raised on a thin layer of soil and farm yard manure (FYM) @ 3:1 placed on a polythene sheet. The thickness of soil+FYM layer was kept at exactly 2.5 cm to facilitate the picking of seedlings from the tray of the transplanter. The polythene sheet prevents the seedling roots from penetrating the underlying soil, creating a dense mat. After seeding, the seeds were covered with straw and was watered twice daily for initial 3-4 days. The straw materials were removed when the seedlings attained a height of 2 cm. Foliar nutrition in the form of 2% Di Ammonium Phosphate (DAP) was given at 10 days after seeding. Seedlings were ready for transplanting in 18 days. The mat was cut into desired shapes and sizes (61 cm X 22.5 cm X 2.50 cm) to fit into the trays of the transplanter. Conventional raised nursery bed was prepared with a width of 4 feet for PTR. The final land was prepared by two passes of rotovator followed by exposure to sun for a period of two weeks and then inundation of the field, ploughing twice again with cultivator and once with rotavator and harrowing with standing water. The seedlings raised in conventional nursery beds were transplanted manually at 30 days. For UPTR and PTR, seedlings were transplanted through transplanter and manual labour, respectively, in rows 20 cm apart to get desired plant population. 3-4 seedlings hill^{-1} was set in transplanter for UPTR as well as under manual transplanting for PTR. The fertilizer dose was 80-40-40 (N- P_2O_5- K_2O kg ha^{-1}). Full P and K along with half of the N was applied as basal during final land preparation, while the rest half of the N was applied in two equal splits, i.e. , once at 3 weeks after transplanting and the next one at 6 weeks after transplanting. Urea, SSP and MOP were used as the source of N, P and K, respectively. No land preparation was done for zero tillage and bed planting. The initial source of nutrients for both ZT and BP were IFFCO (10-26-26), while for top-dressing urea was used.

The previous crop in the rotation, wheat, was harvested manually with the help of sickle keeping 15 cm stubble in the field. In PTR and UPTR plots, where ploughing was done before transplanting, previous wheat crop residues were incorporated while in DSR and BP plots, these residues were kept as mulch which decomposed gradually with the advancement of growth.

In zero tillage and bed planting plots for killing the existing weeds, Glyphosate 41% S.L. @ 3.75 litre ha-1 in 550 litre of water was applied 7 days prior to sowing. In zero tillage and bed planted plots, broad-leaved weeds were controlled with bispyribac-Na @ 25 g a.i. ha^{-1} at 20 days after sowing. In UPTR plots, weeds were killed through application of pre-emergence pendimethalin @ 1 kg a.i. ha^{-1} at 1 day after transplanting followed by post-emergence bispyribac-Na @ 25 g a.i. ha^{-1} at 20 days after transplanting. However, in conventional tillage plots, thinning and weeding were done manually twice, once at 3-4 weeks after transplanting and rest one at 6 weeks after transplanting. Harvesting of the experimental plots (half of the plots were demarcated for determining yield) was done excluding the border rows. After harvesting, the produce was threshed and grains were dried to record yield.

The energy values for various inputs (seeds, fertilizer, superior chemicals like herbicides , diesel fuel, farm machinaries and labour) and outputs (grain and straw) were estimated using energy equivalents as recommended by Mittal and Dhawan (1988). The details on energy equivalents are given in the following Table 1.

The following energy parameters were calculated as suggested by Singh et al. (1997).

Energy efficiency=[Energy output (MJ ha^{-1})/ Energy input (MJ ha^{-1})]

Net energy (MJ ha^{-1})=[Energy output (MJ ha^{-1})-Energy input (MJ ha^{-1})]

Energy productivity (kg MJ^{-1})=[Output (grain+stover) (kg ha^{-1})/Energy input (MJ ha^{-1})]

Total cost of production ha^{-1} for each treatment was calculated on the basis of existing market rate of inputs. Gross return was calculated also on the basis of prevailing market price of the products and accordingly net return was calculated. On the basis of benefit-cost ratio, the most beneficial treatment for the crop sequence was determined.

Table 1. Energy equivalents for different inputs and outputs.

Particulars	Units	Equivalent energy (MJ)
A. Input		
1. Human labour		
(a) Adult man	Man-hour	1.96
(b) Woman	Woman-hour	1.57
2. Diesel	L	56.31
3.Machinery		
(a) Electric motor	kg	64.8
(b) Farm Machinery including self propelled machines	kg	62.7
4. Chemical fertilizer		
(a) Nitrogen	kg	60.60
(b) Phosphate (P2O5)	kg	11.1
(c) Potash (K2O)	kg	6.7
5. Chemicals		
(a) Superior chemicals	kg	120
B. Output		
I. Main product		
(a) grain	kg	14.7
II. By product		
(a) straw	kg	12.5

RESULTS AND DISCUSSION

Grain yield

Perusal of data presented in table 2 indicated the superiority of PTR in first year and UPTR in second year in terms of grain yield. In the first year PTR recorded significantly higher grain yield (4502 kg ha^{-1}), while UPTR recorded maximum grain yield(4616 kg ha^{-1}) during second year of experimentation, being at par with PTR (4606 kg ha^{-1}) . Among the crop establishment techniques DSR recorded the lowest grain yield (2254 and 2750 kg ha^{-1} during 2015 and 2016, respectively). Direct seeding as well as bed planting showed the lesser grain yield. It was due to the lower number of plant population and effective tillers under those two establishment techniques. This lower number of effective tillers was attributed to poor establishment of the crop due to high amount of rainfall received within couple of days of seeding. Under PTR, puddling resulted in more water availability throughout the growing period which in turn reduced the weed problem also. Again, weeds were controlled manually in PTR indicating maximum weed control efficiency leading to higher yields. However, in UPTR, weeds were controlled through herbicides including pre-emergence as well as post-emergence herbicides. Moreover, applying non-selective herbicide (glyphosate) before land preparation might be helpful to control the initial flushes in better fashion. 8-Row paddy transplanter did not encounter any difficulty to transplant seedlings in unpuddled field due to soil softness as water was applied before transplanting and soil was sandy loam. Moreover, the advantage of young seedling transplanting was fully exploited under UPTR. The soil type may interact with the length of wetting in order to facilitate UPTR. The present experiment showed that grain yield in UPTR of rice was similar to PTR indicating that tillage intensity can be reduced to a significant extent to establish transplanted rice without sacrificing yield. Islam et al. (2014) concluded from a trial on UPTR that tillage intensity could be reduced to establish transplanted rice without sacrificing yield. Single pass wet tillage could be promoted in the traditional puddled rice cultivation. Higher grain yield under unpuddled mechanical transplanting was also reported by Rakesh Kumar (2011).

Grain yield varied significantly among the varieties in both the years of experimentation (Table 2). Swarna Sub 1 (3779 kg ha^{-1}) in first year and Pratiksha (4215 kg ha^{-1}) in second year recorded maximum grain yield. There was no significant difference in grain yield between Swarna Sub 1, Pratiksha and MTU 7029. Naveen (2995 and 3370 kg ha^{-1} during year I and year II, respectively) recorded lower yields in both the years. Pratiksha, MTU 7029 and Swarna-Sub 1 performed better under PTR as well as UPTR than rest of the varieties. Among the varieties, Pratiksha was supposed to be superior even under DSR and BP. Different varieties exhibited different growth patterns for which the dry matter accumulation vis-a-vis economic yield varied among varieties.

Labour, fuel and time saving

Among four different crop establishment techniques, PTR consumed maximum man-days and fuel as compared to other crop establishment techniques (Table 3). Puddling, for which maximum number of tillage operations was performed, increased the fuel

Table 2. Grain yield of different rice varieties under various crop establishment techniques.

Variety	Grain yield(kg ha^{-1})									
	2015					2016				
	DSR	BP	UPTR	PTR	Mean	DSR	BP	UPTR	PTR	Mean
Swarna Sub 1	2410	2964	4760	4980	3779	2780	2820	4190	4510	3575
Pratiksha	2240	3100	4195	4860	3599	3370	3310	5120	5060	4215
IET 5656	2130	2940	4080	4150	3325	2210	2630	4850	4490	3545
Naveen	1930	2850	3420	3780	2995	2460	2980	3950	4090	3370
MTU 7029	2560	3280	4250	4740	3708	2930	3390	4970	4880	4043
Mean	2254	3027	4141	4502		2750	3026	4616	4606	
	CET	V	CETXV	VXCET		CET	V	CETXV	VXCET	
SEm(±)	58.79	115.53	231.07	214.11		50.29	125.70	251.41	230.43	
CD(P=0.05)	203.45	332.82	NS	NS		174.05	362.13	NS	NS	

Table 3. Fuel and man-days required for rice under various crop establishment techniques.

Items	PTR		UPTR		DSR		BP	
	Fuel (L/ha)	Mandays (No/ha)	Fuel (L/ha)	Mandays (No/ha)	Fuel (L/ha)	Mandays (No/ha)	Fuel (L/ha)	Mandays (No/ha)
Land preparation	64.50	8 (including	24.75 nursery bed preparation)	10(including mat nursery preparation)	-	-	-	-
Seeding	-	-	-	-	9.750	4	12.00	6
Transplanting	-	25	3.75	6	-	-	-	-
Nutrient application	-	3	-	3		3	-	3
Irrigation management	-	-	-	-	-	-	-	-
Weeding	-	30+20 (twice, manual)	-	3 (chemical)	-	3 (chemical)	-	3 (chemical)
Harvesting	-	25	-	25	-	25	-	25
Drying and Threshing	-	20	-	20	-	20	-	20
Total	64.50	131	28.50	67	9.750	55	12.00	57

requirement to a significant extent under PTR. Manual transplanting as well as manual weeding required higher man-days for which man-days requirement was also much higher (131) under PTR. For other crop establishment techniques weeding were performed with use of herbicides which curtailed down the labour requirement (67 under UPTR, 55 under DSR and 57 under BP) to a considerable extent. In PTR, two cultivator + one rotavator was given initially, after which the land was kept undisturbed for 20 days and during final land preparation another two rotavator was given which triggered the fuel requirement to the maximum extent (64.50 L ha^{-1}). Under UPTR, only a single pass through power tiller was performed for land preparation for which the fuel requirement was much lower (28.50L ha^{-1}) as compared to PTR. As seeding and secondary tillage was performed simultaneously under DSR and BP with zero till drill and bed planter, respectively, under these two crop establishment techniques maximum saving in fuel was occurred.

All the alternate crop establishment techniques were efficient in saving a considerable time required for land preparation and transplanting. BP and UPTR resulted in 69.69 and 37.57 % time saving over PTR respectively (Table 4). While, DSR saved 78.78% time in land preparation as well as transplanting. Direct seeding under DSR and BP resulted in this sort of time saving due to complete avoidance of transplanting as in case of PTR and UPTR. Islam et al. (2014) reported that minimum tillage like unpuddled strip tillage or single pass wet tillage saved about 30-54% fuel consumption and 40-49% labour requirement compared to CT in land preparation.

Rice energetics

The input and output energy values presented in Table 5 revealed that the total input energy was maximum under PTR (10862.30 MJ ha^{-1}). Consumption of maximum human labour towards transplanting, weeding, harvesting and threshing as well as consumption of huge diesel fuel for repeated tillage operations under puddle situation was the prime reason for the highest total energy input under PTR. It was to be mentioned that there was no input energy required under PTR for use of farm machinery while UPTR, BP, and DSR consumed energy of 846.45, 391.90 and 274.30 MJ ha^{-1}, respectively for driving those machineries only while seeding/transplanting. The input energy for fertilizer consumption recorded equal with all the crop establishment techniques as the dose was same for the crops under all establishment techniques. For other alternate crop establishment techniques, total energy input was reduced to 9269.95, 7865.00 and 7589.30 MJ ha-1 under UPTR, BP and DSR, respectively due to less fuel and labour consumption. In PTR, two cultivators + three rotavator was given for pudddling which triggered the input energy value to 3632.00 MJ ha^{-1}under diesel fuel. Input energy requirement was lower under diesel fuel in UPTR (1604.80 MJ ha^{-1}) due to only one rotavator + one cultivator for final land preparation compared to PTR. Maximum saving in total energy input under BP (7865.00 MJ ha^{-1}) and DSR (7589.60 MJ ha^{-1}) was achieved due to comparatively

Table 4. Time saving for land preparation in rice under various crop establishment techniques.

Crop establishment techniques	Time required for land preparation and transplanting(Hr./ha)	Time saving (%)
Puddled Transplanting(PTR)	10.625 + 10 (with 25 man-days)=20.625	-
Unpuddled Transplanting(UPTR)	4.125 + 8.75=12.875	37.57
DSR	4.375(together with seeding)	78.78
Bed Planting	6.25(together with seeding)	69.69

less consumption of diesel fuel and human labour than PTR and UPTR. The lowest total energy input was recorded under DSR among the all crop establishment techniques.

Total energy output was recorded maximum under PTR (155256.30 MJ ha^{-1}) followed by UPTR (147283.80 MJ ha^{-1}) due to higher grain and straw yield production compared to other crop establishment techniques. Under BP total energy output was recorded 110296.90 MJ ha^{-1}, while under DSR the total energy output was only 93281.60 MJ ha^{-1}; the lowest total energy output under DSR attributed to minimum grain and straw yield of rice achieved. Net energy gain was recorded maximum under PTR (144394.00 MJ ha^{-1}) and minimum under DSR (85692.30 MJ ha^{-1}) among the crop establishment techniques. It was interesting to note that despite higher output energy and net energy gain under PTR, energy efficiency was recorded maximum under UPTR (15.88 MJ ha^{-1}) reflecting its higher efficiency over other crop establishment techniques. The energy efficiency of BP and PTR were very close (14.02 MJ ha-1 under BP and 14.29 MJ ha^{-1} under PTR) respectively. DSR recorded the lowest energy efficiency (12.29 MJ ha^{-1}) among the all crop establishment techniques.

Energy productivity showed similar trend like energy efficiency. UPTR recorded highest energy productivity (1.19 kg MJ^{-1}) followed by PTR (1.07 kg MJ^{-1}) and BP (1.05 kg MJ^{-1}). Among the all crop establishment techniques DSR recorded the lowest energy productivity (0.93 kg MJ^{-1}).Very poor yield performance under DSR due to poor crop stand attributed to this. It was clear that alternate tillage operations could increase the energy efficiency and energy productivity to a significant extent. Unpuddled transplanting showed 8-12% increase in energy productivity and 22-24% increase in energy output: input ratio. However, from the energy saving point of view, unpuddled transplanting may be considered better options depending on the resources availability in rice cultivation (Islam et al., 2013).

Production economics

As far as cost of production was concerned the maximum cost of cultivation was recorded under PTR irrespective of varieties during both the years and it was significantly higher over the other crop

Table 5. Energy relations in rice as influenced by crop establishment techniques.

Energy relations	DSR	BP	UPTR	PTR
Energy inputs(MJ ha^{-1})				
Human labour	722.00	753.40	832.70	1670.30
Diesel fuel	549.00	675.70	1604.80	3632.00
Farm machinery including self	274.30	391.90	846.45	-
Fertilizer N	4848.00	4848.00	4848.00	4848.00
Fertilizer P	444.00	444.00	444.00	444.00
Fertilizer K	268.00	268.00	268.00	268.00
Herbicides	484.00	484.00	426.00	-
Total energy	7589.30	7865.00	9269.95	10862.30
Energy output (MJ ha^{-1})				
Grain	36794.10	44496.90	64371.30	66943.80
Straw	56487.50	65800.00	82912.50	88312.50
Total output	93281.60	110296.90	147283.80	155256.30
Net energy gain (MJ ha^{-1})	85692.30	102431.9	138013.85	144394.00
Energy efficiency	12.29	14.02	15.88	14.29
Energy productivity(kg MJ^{-1})	0.93	1.05	1.19	1.07

Table 6. Production economics of rice under various treatment combinations.

Treatments	Cost of cultivation (Rs. ha^{-1})		Gross Return (Rs. ha^{-1})		Net Return (Rs. ha^{-1})		B:C ratio	
	2015	2016	2015	2016	2015	2016	2015	2016
DSR-Swarna Sub 1	21478.00	21728.00	26510.00	31970.00	5032.00	10242.00	1.23	1.47
DSR-Pratiksha	21478.00	21728.00	24640.00	38755.00	3162.00	17027.00	1.15	1.78
DSR-IET 5656	21478.00	21728.00	23430.00	25415.00	1952.00	3687.00	1.09	1.17
DSR-Naveen	21478.00	21728.00	21230.00	28290.00	-248.00	6562.00	0.99	1.30
DSR-MTU 7029	21478.00	21728.00	28160.00	33695.00	6682.00	11967.00	1.31	1.55
BP-Swarna Sub 1	22022.00	22272.00	32604.00	32430.00	10582.00	10158.00	1.48	1.46
BP-Pratiksha	22022.00	22272.00	34100.00	38065.00	12078.00	15793.00	1.55	1.71
BP-IET 5656	22022.00	22272.00	32340.00	30245.00	10318.00	7973.00	1.47	1.36
BP-Naveen	22022.00	22272.00	31350.00	34270.00	9328.00	11998.00	1.42	1.54
BP-MTU 7029	22022.00	22272.00	36080.00	38985.00	14058.00	16713.00	1.64	1.75
UPTR-Swarna Sub 1	22792.00	23042.00	52360.00	48185.00	29568.00	25143.00	2.30	2.09
UPTR-Pratiksha	22792.00	23042.00	46145.00	58880.00	23353.00	35838.00	2.02	2.56
UPTR-IET 5656	22792.00	23042.00	44880.00	55775.00	22088.00	32733.00	1.97	2.42
UPTR-Naveen	22792.00	23042.00	37620.00	45425.00	14828.00	22383.00	1.65	1.97
UPTR-MTU 7029	22792.00	23042.00	46750.00	57155.00	23958.00	34113.00	2.05	2.48
PTR-Swarna Sub 1	35796.00	36046.00	54780.00	51865.00	18984.00	15819.00	1.53	1.44
PTR-Pratiksha	35796.00	36046.00	53460.00	58190.00	17664.00	22144.00	1.49	1.61
PTR-IET 5656	35796.00	36046.00	45650.00	51635.00	9854.00	15589.00	1.28	1.43
PTR-Naveen	35796.00	36046.00	41580.00	47035.00	5784.00	10989.00	1.16	1.30
PTR-MTU 7029	35796.00	36046.00	52140.00	56120.00	16344.00	20074.00	1.46	1.56
	CET	V	CET	V	CET	V	CET	V
SEm(±)	602.30	859.60	931.50	1259.30	394.10	502.10	0.20	0.31
CD(P=0.05)	2078.00	NS	3213.67	3614.20	1359.50	1441.10	0.69	0.89

establishment techniques. Among various crop establishment techniques, DSR and BP had less cost involvement. No extra cost was incurred towards land preparation both under DSR and BP for which the cost of cultivation was much lesser in these two techniques. Moreover, chemical weed control was performed in these two types of crop establishment techniques which resulted in a further savings in total cost of cultivation over PTR. Less fuel requirement as well as less labour engagement in UPTR also resulted in lesser cost of cultivation compared to PTR. Haque et al. (2013) reported that tillage cost for land preparation was significantly lower where single-pass minimum tillage was used. Thakur (1993) found that cost of cultivation was 8.87% lower in direct seeded rice, which was much higher in transplanting method.

Gross and net returns were significantly influenced by crop establishment techniques as well as varieties. Maximum gross return of Rs. 54,780.00 and Rs. 58,880.00 ha^{-1} was obtained from the treatment with variety Swarna Sub 1 under PTR and Pratiksha under UPTR during year I and year II, respectively (Table 6). It was closely followed by the variety Pratiksha (Rs. 53,460.00 ha^{-1}) under PTR in the first year, while MTU 7029 (Rs. 57,155.00 ha^{-1}) under UPTR in the second year. In general, the return of all the varieties was much higher under PTR in the first year, while in the second year, the overall gross returns were higher under UPTR. This variation in gross return was attributed to the difference in yield achieved under PTR and UPTR during two separate years of experimentation. Despite higher gross returns under PTR, UPTR reflected a higher net return in both the year of experimentation. As the yields were similar in PTR and UPTR, reduced cost of cultivation under UPTR resulted in much higher net returns for all the varieties. Among the varieties, higher returns were registered with Pratiksha under both PTR and UPTR. Due to poor yield performance under DSR and BP, the gross and net returns were much lower compared to PTR and UPTR in all the varieties.

Despite higher yield and gross returns achieved with PTR, benefit-cost ratio was significantly higher in UPTR (1.65 to 2.30 and 1.97 to 2.56 during year I and II, respectively) in all the varieties in both the years (Table 5). Lesser cost involvement with higher yield performance under UPTR resulted in superior B:C ratio over PTR. Sharma et al. (2007) reported that amongst varying crop establishment methods, self-propelled transplanter gave the maximum net return (Rs. 44,559.00 ha^{-1}) and benefit:cost ratio (1.47). In some cases, DSR recorded B:C ratio less than 1.00 i.e., less remunerative with Naveen, reflecting its poor performance despite lesser cost of cultivation.

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