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Effect of crop establishment methods on productivity, profitability and energetics of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system

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ABSTRACT

A field experiment was carried out from 2007-08 to 2009-10 at Varanasi, Uttar Pradesh to compare the performance of four crop establishment methods (direct dry seeding by zero till drill, direct seeding of sprouted rice seeds in puddled field by drum seeder, hand transplanting and mechanical transplanting through SPT in rice and four tillage methods (rotavator, conventional sowing, strip and zero till drilling) in wheat on productivity, profitability and energetics of rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system. Results revealed that hand and mechanical transplanting by SPT of rice (PHB 71) being at par, produced significantly higher grain yield of rice (5.76 and 5.71 tonnes/ha) than direct dry seeding by zero till and direct seeding of sprouted rice by drum seeder under puddled field (3.86 and 4.98 tonnes/ha). However, the use of SPT gave the maximum B:C ratio (2.86) and was significantly superior over hand transplanting (2.58), direct seeding of sprouted rice by drum seeder (2.51) and direct dry seeding by zero till (1.86). In wheat (HD 2733), zero till drill sowing proved most cost effective and recorded markedly higher grain yield (4.05 tonnes/ha), net return (₹ 44 670/ha) and B:C ratio (4.19) but statistically at par with conventional sowing than rotavator and strip till. Consequently, among the rice establishment methods hand transplanting produced the maximum system REY (10.2 tonnes/ha/yr) being at par with mechanical transplanting (10.18 tonnes/ha/yr) and both produced significantly higher REY than drum seeder and zero till drill (9.56 and 8.52 tonnes/ha/yr, respectively). In wheat, zero till drill sowing produced the maximum REY (9.92 tonnes/ha/yr) and being comparable to conventional sowing, rotavator and strip till (9.72, 9.52 and 9.30 tonnes/ha/yr, respectively). The similar trend was followed in system productivity of rice and wheat. Moreover, mechanical transplanted rice by SPT (5.62) followed by zero till drill (6.46) sown in wheat gave the highest energy efficiency than other crop establishments methods by ensuring timely and cheap sowing without sacrificing crop yield.

Key words: CO_2 emission, Crop establishment methods, Energetics, Fuel consumption, Rice-wheat system, Sustainable value index

Among the various cropping systems practiced in India, rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) is considered most important because to its area coverage and contribution to total foodgrain production and mainly practiced in entire Indo-Gangetic plains. Both crops of this cropping system are fertility exhaustive and need more water, labour, time, non-renewable energy, heavy farm machineries and other expenditure. Continued puddling for rice cultivation over decades has led to deterioration of soil physical properties through structural breakdown of soil aggregates and capillary pores and clay dispersion thereby restricting germination and rooting of succeeding crops (Tomar *et al.* 2006). Therefore, it is imperative that alternate method of growing crops that are more water efficient and less labour intensive to be developed to enable farmers to produce more with less cost of production. Huge labours are needed to accomplish transplanting of rice seedlings and mostly it is delayed to a greater extent due to unavailability of adequate labours during transplanting peak. Thus, late planted rice takes more time to reach the maturity, which not only reduces the rice yield but also delays sowing of succeeding crop particularly wheat but direct seeding of rice can reduce the labour and water requirement, shorten the duration of crop by 7-10 days and provide comparable yield with transplanted rice (Mishra *et al.* 2012).

In plains of Eastern India, sowing of wheat gets delayed due to wet condition after rice harvesting which takes much time to come in working condition, also tillage in such soils require more time, labour and energy. On the other hand, zero tillage minimizes loss on account of delayed sowing as it advances the wheat sowing by 10-15 days and also saves the time and cost involved in field preparation. Conventional methods of wheat sowing, which requires excessive tillage delays the sowing and reduce the yield, but the same can be accomplished efficiently with use of improved machines, viz. zero, strip and rotavator till drill etc. to save the time, fuel, energy and cost (Jha *et al.* 2007). It is therefore,

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imperative to identify and quantify the suitable crop establishment methods and planting management for both the crop components under widely spreaded rice-wheat cropping system, which can minimize the consumption of time, fuel, CO_2 emission, energy, money and labour with sustainable productivity of entire cropping system in Indo-Gangetic plains. Keeping these points in view, the present investigations was undertaken.

MATERIALS AND METHODS

The field experiments were carried out at Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh situated at 83° 03'0'' E longitude, 25° 18'0' N latitude and an altitude of 128.93 m msl for three consecutive years, i.e. 2007-08, 2008-09 and 2009-10. The experimental soil was Gangetic alluvial (Ustochrept) with pH 7.3. The soil was moderately fertile being low in organic carbon (0.39%), available N (198.4 kg/ha) and medium in available P (15.7 kg/ha) and available K (215.4 kg/ha) contents. The experiment was laid in strip plot design with three replication The treatments consist of 4 rice crop establishment methods, viz. direct dry seeding by zero-till drill, direct seeding of sprouted seeds by drum seeder in puddled field, hand transplanting and mechanical transplanting through self-propelled transplanter (SPT) with variety PHB 71 in *kharif* season. After harvest of rice, plot divided into four units in vertical strips to facilitate wheat sowing with 4 tillage practices, viz. rotavator till drilling, conventional tillage, strip till drill and zero till drill for wheat variety HD 2733 in *rabi* season. 18 and 24 days old seedlings were used for mechanical transplanting by SPT and manual transplanting, respectively with spacing of 20×15 cm. Tillage operation in direct seeding in dry field were done directly without any primary land preparation and for direct seeding of sprouted seeds through drum seeder in puddle soil and mechanical and hand transplanting consisted of one cultivator, 2 puddling and 1 planking. Butachlor @ 1.5 kg/ha was applied as pre-emergence for weed control in rice and this was supplemented with hand weeding twice at 20 and 40 DAS in direct seeding in dry field, whereas one hand weeding at 40 DAT after in puddled field. After harvesting of rice, a pre-sowing irrigation was given to ensure optimum soil moisture for different methods for wheat sowing. Under zero, strip and rotavator till sowing of wheat was done directly without primary land preparation but sowing under conventional methods in wheat involved 1 cultivator, 2 harrowing and 1 planking. For weed control in wheat, Isoproturon 1.0 kg *a.i* + 0.5 kg/ha 2, 4-D was applied at 30 DAS. For rice, recommended fertilizer, dose of fertilizer, i.e. 150 kg N + 75 kg P_2O_5 + 75 kg K_2O + 30 kg S/ha had applied through 12:32:16 NPK complex, urea, muriate of potash and elemental sulphur. One third of recommended dose of N and entire dose of P, K and S was applied as basal and remaining N was applied in two equal splits through urea at maximum tillering and panicle emergence stage. In wheat, recommended dose of fertilizer i.e. 120 kg N + 60 kg P_2O_5 + 60 kg K_2O were applied through 12:32:16 NPK complex, urea and muriate of potash. Half of recommended dose of N and whole of P and K were applied as basal and remaining doses of N in applied in two equal splits through urea at maximum tillering and spike emergence stages. For calculating the energy input and output through different power sources, viz. labour, fuel, machinery, fertilizer, seeds, pesticides, irrigation and crop yield were calculated by standard energy coefficient (Devasenapathy *et al.* 2009). Sustainable yield index (SYI) and sustainable value index (SVI) were computed by using the formula as suggested by Wanjari *et al.* (2004). The data

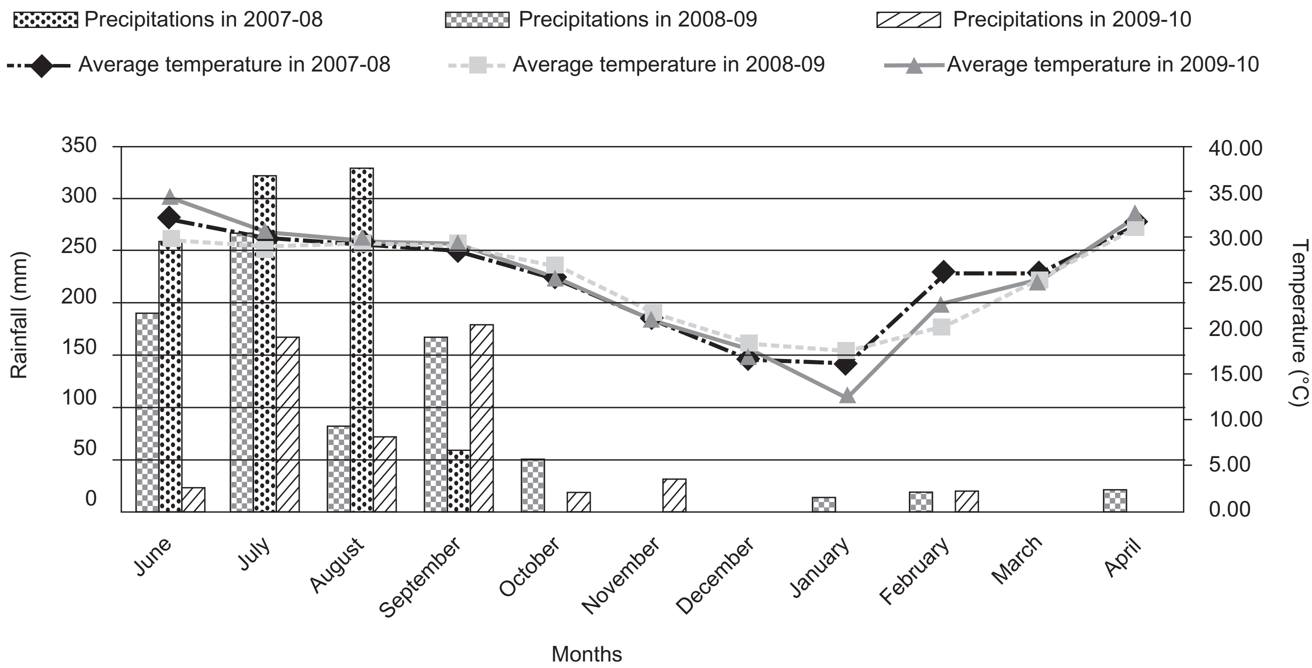

Fig 1 Monthly rainfall and mean temperature during three growing seasons of the experimentation

on grain and straw yields, REY, net monetary returns and benefit: cost ratio obtained during 3 years were pooled and subjected to statistical analysis.

RESULTS AND DISCUSSION

Effect of weather

The weather condition differed markedly during three years of experimentation particularly with respect to rainfall. The rainfall received during 2007-08 (797.1 mm) was less as compared to 2008-09 (963.8) but higher than 2009-10 (499.4 mm). Consequently, more number of irrigation was given to the crops during second and third year. The average temperature particularly at reproductive stages of both the crops was more conducive during second year and third year.

Effect of crop establishment methods on rice

Yield attributes and yield: Grain yield and its component in rice differed significantly with different establishment methods (Table 1). Hand transplanting (5.76 tonnes/ha) though statistically at par with transplanting by SPT (5.71 tonnes/ha) produced significantly higher grain and straw yield than those obtained with direct seeding both under dry and wet condition by zero till and drum seeder under puddled field (3.86 and 4.98 tonnes/ha, respectively). Number of filled grains/panicle and 1 000-grain weight were maximum in hand transplanting closely followed by mechanical transplanting by SPT. Higher grain yield in hand transplanted rice was mainly due to higher yield attributes such as number of grains/panicle and 1 000-grain weight and better crop management practices adopted (Gopal *et al.* 2010). Maximum number of effective tillers/m^2 (235.92) was recorded in mechanical transplanting through SPT followed by direct seeding of sprouted rice seeds by drum seeder (233.58), hand transplanted rice (211.58) and direct dry seeding by zero till drill rice (163.08).Poor performance in direct sowing particularly zero till drill resulted in lowest yield attributes due to less favourable condition for plant stand and growth of crop because of heavy weed competition. These results are in close conformity with finding of Sharma *et al.* (2006), Bohra *et al*. (2006) and Singh *et al*. (2005). The residual effect of the various crop establishment methods of wheat in the previous years on the yield attributes and grain yield of rice was not significant.

Effect of crop establishment methods on wheat

Yield attributes and yield: Different sowing methods of wheat had significant variation in yield attributes, viz. number of effective tillers/m^2, number of grains/spike, 1 000-grain weight and grain yield. Irrespective of the various methods in rice, sowing of wheat by zero till drill significantly increased number of effective tillers/m^2 (336.25), grains/spike (47.3), 1 000-grain weight (38.9) and grain yield (4.05 tonnes/ha) but grains/ spike (46.3) and grain yield (3.98 tonnes/ha) at par with conventional sowing methods. The possible reason for higher grain yield in zero till drill due to better yield attributes by advancing the sowing time but reverses in case of conventional methods due to delayed in sowing (Sharma *et al.* 2006). Significant reduction in yield and yield attributes particularly numbers of effective tillers/m and grains/spike was recorded in strip till drill sown crop. Conventional sowing of wheat produced significantly higher straw yield than rotavator, strip and zero till drill sown crop. Rotavator and strip till drilling also proved significantly superior in

Table 1 Yield attributes and yield of rice and wheat as affected by different crop establishment methods in rice-wheat cropping system (Pooled data of 3 years)

Crop establishment methods	Rice						Wheat					
	Effective tillers/m^2	Panicle length (cm)	Grains/ panicle	1 000-gain wt. (g)	Grain yield (tonnes /ha)	Straw yield (tonnes /ha)	Effective tillers/ m	Spike length (cm)	Grains/ spike	1 000-grain weight (g)	Grain yield (tonnes/ ha)	Straw yield (tonnes/ ha)
Rice												
Direct dry seeding by zero-till drill	163.08	27.77	131.06	18.28	3.86	3.77	301.58	9.13	46.08	34.40	3.99	5.85
Direct seeding of by Drum seeder	233.58	27.79	141.67	19.23	4.98	5.59	297.83	9.21	45.34	35.40	3.93	5.92
Hand Transplanting	211.58	27.59	155.42	21.11	5.76	5.82	293.92	9.15	46.20	36.17	3.80	5.80
Mechanical Transplanting	235.92	27.63	149.39	20.67	5.71	6.22	291.83	9.17	45.16	36.37	3.83	6.01
CD (*P=0.05*)	13.46	NS	16.96	1.22	0.34	0.38	NS	NS	NS	NS	NS	NS
Wheat												
Rotavator till drilling	207.67	27.74	144.57	19.38	5.02	5.17	286.33	9.11	43.78	34.80	3.86	5.95
Conventional sowing	212.25	27.49	146.46	20.32	5.00	5.37	294.50	9.26	46.31	32.73	3.98	6.43
Strip till drilling	212.67	27.73	141.36	20.12	5.02	5.31	268.08	9.12	45.39	35.90	3.67	5.56
Zero till drilling	211.58	27.81	145.15	19.48	5.28	5.54	336.25	9.18	47.30	38.90	4.05	5.65
CD (*P=0.05*)	NS	NS	NS	NS	NS	NS	19.17	NS	2.27	1.53	0.18	0.26

Table 2 Economics of rice and wheat as affected by different crop establishment methods under rice-wheat cropping system (Pooled data of 3 years)

Crop establishment methods	Rice				Wheat			
	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
Rice								
Direct dry seeding by zero-till drill	21 570	40 410	18 840	1.87	14 968	59 490	44 522	4.00
Direct seeding by drum seeder	21 192	53 182	31 990	2.51	14 968	58 991	44 024	3.96
Hand transplanting	23 483	60 591	37 108	2.58	14 968	57 333	42 365	3.85
Mechanical transplanting	21 252	60 743	39 491	2.86	14 968	58 244	43 277	3.92
CD (P=0.05)	-	3531	3531	0.16	-	NS	NS	NS
Wheat								
Rotavator till drilling	21 874	52 901	31 027	2.42	14 239	58 344	44 105	4.10
Conventional sowing	21 874	53 026	31 152	2.42	17 490	61 833	44 343	3.54
Strip till drilling	21 874	53 164	31 289	2.43	14 122	55 193	41 071	3.91
Zero till drilling	21 874	55 836	33 962	2.55	14 019	58 689	44 670	4.19
CD (P=0.05)	-	NS	NS	NS	-	2480	2480	0.15

Price of rice: ₹ 900 and straw: ₹ 150, Price of wheat: ₹ 1 050 and straw: ₹ 300

respect of straw yield of wheat as compare to zero till drilling. This could be described to 20 cm straw left in field under zero till drill sown wheat. These findings are in close agreement with Bohra *et al.* (2006). The residual effect of the various crop establishment methods of rice in previous years on the yield attributes and grain yield of wheat was not significant.

Economics

Mechanically transplanted rice through SPT gave maximum benefit: cost ratio (2.86) and net income (₹ 39 491/ha), hence proved more remunerative than other methods of crop establishment (Table 2). This was ascribed to higher grain yield and minimum cost of production under SPT. The next best treatment was hand transplanted rice in terms of benefit: cost ratio (2.58) and net income (₹ 37 108/ha). These results are in close conformity with the findings of Singh *et al.* (2005), Sharma *et al.* (2006) and Bohra *et al*. (2006). However, direct dry seeding by zero till fetched the minimum net monetary returns (₹ 18 840/ha) and B:C ratio (1.87) of rice mainly due lower yield. Among different sowing methods of wheat, zero till drill sowing gave the maximum net returns (₹ 44 670/ha/yr) and B: C ratio (4.19) but was at par with rotavator till drilling (₹ 44 105/ha/yr and B: C ratio 4.10) and this was mainly by due to saving on fuel (diesel). The next sowing method of wheat was conventional sowing with net returns of ₹ 44 343/ha/yr and B: C ratio of 3.54 followed by strip till drilling (₹ 41 071/ha/yr and B: C ratio of 3.91). Though conventional sowing of wheat fetched higher gross return than zero till, strip till drill and rotavator planting but net returns and B:C ratio reversed for them because of more cost of investment required in conventional sown wheat than zero, strip and rotavator till drill. Sharma *et al.* (2007), Kewat *et al.* (2011) and Brar *et al.* (2011) also reported similar results.

Effect of crop establishment methods on rice - wheat system

System rice equivalent yield: Total productivity of rice-wheat system as a whole was determined in rice equivalent yield (REY) for all the treatments (Table 3). Manually transplanted rice gave highest system productivity (10.2 tonnes/ha/yr) and proved significantly better than other two methods of crop establishments, viz. direct seeding of sprouted rice seed by drum seeder (9.56 tonnes/ha/yr) and direct dry seeding by zero till drill (8.52 tonnes/ha/yr) but at par with mechanical transplanting by SPT (10.18 tonnes/ha/yr). Direct seeding of sprouted seeds by drum seeder was also found better over direct dry seeded by zero till drill rice. These observations were in agreement with findings of Gangwar *et al.* (2010). In wheat, zero till drill sowing gave significantly higher SREY (9.92 tonnes/ha/yr) among all sowing methods. Further, system profitability and system net return were recorded significantly higher in mechanical transplanting by SPT over direct seeding by drum seeder and zero till drill but statistically at par with hand transplanting. Similar findings were reported by several workers from their studies in different rice-wheat growing areas of the country (Jha *et al.* 2007). However in case of wheat, system net return (₹ 78 632/ha/yr) and system profitability (₹ 314.68/ha/yr) were recorded under zero till which was comparatively higher over other crop establishments methods. Ram *et al.* (2006) also reported higher productivity and profitability of rice-wheat system with transplanting than dry seeding methods in rice.

System production efficiency, system net return, system profitability and sustainable yield and value index

System production efficiency refers to per day productivity of entire cropping system under a particular treatment. Thus, productions efficiency depends on the quantum of total production as well as duration of total crop

Table 3 System rice equivalent yield (SREY), sustainable yield index and sustainable value index (SYI and SVI), system productivity and profitability and energetics of rice - wheat under different crop establishment methods in rice-wheat cropping system (Pooled data of 3 years).

Crop establishment methods	SREY (tonnes/ ha/yr)	SYI	SVI	System productivity (kg/ha/day)	System net return (₹/ha/yr)	System profitability (₹/ha/day)	Energy input (MJ/ha)	Energy output (MJ/ha)	Specific energy (MJ/kg)	Energy producti- vity (kg/MJ)	Energy effici- ency
Rice											
Direct dry seeding by zero-till drill	8.52	0.42	0.32	23.34	63 363	273.70	20 283	103 866	2.66	0.38	5.12
Direct seeding by Drum seeder	9.56	0.63	0.48	26.19	76 014	307.33	26 508	143 007	2.51	0.40	5.39
Hand transplanting	10.20	0.77	0.68	27.94	79 474	323.08	32 138	157 454	2.78	0.36	4.90
Mechanical transplanting	10.18	0.76	0.73	27.89	82 768	325.99	28 788	161 745	2.41	0.41	5.62
CD (*P=0.05*)	0.50			1.37	5494	15.05					
Wheat											
Rotavator till drilling	9.52	0.64	0.96	26.07	75 132	304.78	21 515	131 052	2.07	0.48	6.09
Conventional sowing	9.72	0.64	0.94	26.63	75 495	313.77	23 858	139 976	2.55	0.39	5.87
Strip till drilling	9.30	0.63	0.87	25.49	72 360	296.87	19 888	123 386	3.48	0.29	6.20
Zero till drilling	9.92	0.67	0.96	27.17	78 632	314.68	19 976	129 059	2.97	0.34	6.46
CD (P=0.05)	NS			NS	NS	NS					

period under a particular treatment. Manual transplanted rice had the highest system production efficiency (27.94 kg/ha/day) closely followed by mechanically transplanted rice through SPT (27.89 kg/ha/day) and was significantly higher than direct dry seeding by zero till drill (23.34 kg/ha/day) and direct seeding of sprouted rice by drum seeder (26.19 kg/ha/day). Similarly, zero till drill sown wheat had recorded the maximum production efficiency (27.17 kg/ha/day), closely followed by conventional sowing (26.63 kg/ha/day) and rotavator till drill (26.07 kg/ha/day). System net return and system profitability was noted maximum under mechanical transplanted rice through SPT (₹ 82 768 ha/yr and ₹ 325.99/ha/day), which was at par with hand transplanting (₹ 79 474/ha and ₹ 325.99/ha/day) and significantly higher over direct seeding by sprouted rice seed by drum seeder (₹ 76 014/ha and ₹ 323.08/ha/day) and direct dry seed by zero till (₹ 63 363/ha and ₹ 273.70/ha/day). This might be due to higher yield in rice and wheat in respective crop establishment methods. The residual effect of the various crop establishment methods of wheat in the previous year on SREY, system productivity, system net return and system profitability was not significant.

The sustainable yield index and sustainable value index (SYI and SVI) value was determined on basis of total productivity and net return of entire rice-wheat system for 4 years under each treatment. The higher values of SYI in rice was recorded under hand transplanting (0.77) closely followed by mechanical transplanting by SPT (0.76) and direct seeding by drum seeder (0.63), whereas lowest with direct seeding by zero till drill (0.42), respectively (Table 3). Similar, trends were followed in sustainable value index (SVI) in rice, where the highest SVI were recorded in SPT (0.73) followed by hand transplanting (0.68) and direct seeding by zero till (0.22).Thus, yield in hand and mechanical transplanting were proved to be more sustainable for higher productivity and profitability of rice-wheat system than growing of rice by direct seeding either by zero till and drum seeder. However, SYI in wheat was maximum with zero till drill (0.67) among all sowing methods, which markedly declined to 0.64, 0.64 and 0.63 owing to conventional sowing, rotavator and strip till, respectively. Similar results were obtained in wheat with regards to SVI, both zero and rotavator till sown wheat recorded the higher SVI (0.96) closely followed by conventional sowing (0.94), whereas strip till recorded the lowest (0.87) (Table 3). These findings are in close conformity with Jha *et al.* (2007).

Effect of crop establishment methods on rice - wheat system on energetics

Energy is one of the most important indicators of crop performance (Singh *et al*. 2008). Net energy and monetary return of cropping system can be quantified for sound planning of sustainable system (Chaudhary *et al.* 2006). The comparison of energy use pattern (Table 4) in different crop establishment methods of rice revealed that highest input energy (32 138 MJ/ha) were consumed in manually transplanted rice and closely followed by mechanically transplanted rice (28 788 MJ/ha) and direct seeding of sprouted rice seed by drum seeder (26 508 MJ/ha). The lowest energy was consumed under direct seeding of rice by zero till (20 508 MJ/ha). However, output energy was the highest in mechanical transplanting (161 745 MJ/ha) closely followed by manual transplanted rice (157 457 MJ/ha), direct seeding by drum seeder rice (143 007 MJ/ha) and the lowest in direct dry seeding by zero till drill rice

Table 4 Traction power, time and fuel consumption and saving, CO_2 emission and consumption of equivalent energy in rice and wheat in rice-wheat cropping system under different crop establishment methods (Pooled data of 3 years).

Crop establishment methods	Tractor operation (No. of pass)	Time (hr/ha)	Fuel consumption (l/ha)	Fuel saving (%)	Time saving (%)	CO_2 emission (kg/ha)	Consumption of equivalent energy (MJ/ha)
Rice							
Direct dry seeding by zero-till drill	1	3.91	11.73	85.83	80.13	30.49	660.52
Direct seeding by Drum seeder	4	19.68	82.80	-	-	215.28	4 662.47
Hand transplanting	4	19.68	82.80	-	-	215.28	4 662.47
Mechanical transplanting	3	16.99	62.54	24.47	13.69	162.60	3 221.63
Wheat							
Rotavator till drilling	1	6.39	28.48	50.13	53.69	74.05	1 603.71
Conventional sowing	3	13.80	57.11	-	-	148.69	3 215.86
Strip till drilling	1	5.33	25.58	55.21	61.38	66.51	1 440.41
Zero till drilling	1	3.5	10.50	81.61	74.64	27.3	591.25

Note: 1 litre diesel consumed energy = 56.31 MJ and 1 litre diesel emits: 2.6 kg CO_2

(103 866 MJ/ha). Similarly, conventional sown wheat consumed the highest input energy (23 858 MJ/ha) among all crop establishment methods used. Other tillage methods of wheat consumed almost equal energy ranging between 19 888 to 21 575 MJ/ha. The higher energy consumption under conventional sowing when compare with zero, strip and rotavator till drill due to more tillage operation (Jain *et al.* 2007). The energy use efficiency was maximum (5.62) by growing rice through mechanical transplanting by SPT closely followed by direct seeding of sprouted rice seed through drum seeder (5.39) and manual transplanting (4.9). Similarly, zero till sown wheat had the maximum energy use efficiency (6.46) closely followed by strip till sowing (6.2) and rotavator (6.09) and conventional sowing had minimum energy use efficiency (5.87).The higher energy use efficiency under a particular sowing method of a crop was mainly attributed to higher energy production with the use of relatively lesser energy utilization.

The comparison of traction power, time and fuel saving, CO_2 emission and consumption of equivalent energy use pattern (Table 4) in different crop establishment methods of rice revealed that the highest traction power (4), time (19.62 hr/ha) and fuel saving (82.8/ha), CO_2 emission (215.88 kg/ha) and consumption of equivalent energy use (4 662.47 MJ/ha) were consumed in hand transplanted rice and direct seeding of sprouted rice by drum seeder closely followed by mechanically transplanted rice through SPT (3 221.63 MJ/ha). The lowest traction power, time and fuel saving, CO_2 emission and consumption of equivalent energy was consumed under direct seeding of rice (39 514 MJ/ha). In respect to fuel and time saving, direct dry seeding by zero till drill saves 85.83 and 80.13 per cent fuel consumption and time, respectively as compared to hand transplanting and direct seeding of sprouted rice by drum seeder in rice field but in comparison to mechanical transplanting through self-propelled transplanter, it saves only 24.17 and 13.69% on fuel and time, respectively. Similarly, conventional till sown wheat had the highest traction power (4), CO_2 emission (148.69 kg/ha) and consumption of equivalent energy (3 215.86 MJ/ha) among all crop establishment methods. However, the lowest traction power (1), CO_2 emission (27.3 kg/ha) and consumption of equivalent energy (591.25 MJ/ha) in zero till drill sowing. In terms of fuel and time saving in rice transplanted by SPT was 24.47 and 13.19%, respectively over hand transplanting. Similarly, fuel and time saving in wheat by zero till drill was (81.61 and 74.64 per cent), strip till (55.21 and 61.38%) and rotavator till (50.13 and 13.69%), respectively. as compared to conventional sowing wheat.

Thus, it was concluded that mechanically transplanted rice through SPT and zero till drill methods for wheat sowing are the best crop establishment methods for higher yield, profitability and energetics point of view, which can minimize on the consumption of time, energy, CO_2 emission, money and labour while sustaining productivity of entire cropping system in Indo-Gangetic plains of irrigated condition of Eastern Uttar Pradesh on a long-term basis.

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