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ENERGY AND ECONOMIC ASSESMENT IN TILLAGE AND SOWING FOR ROTAVATORS, CONVENTIONAL AND NO-TILL WHEAT ESTABLISHMENT

SUMMARY

Rice-wheat is major crop of IGP covering around 10 Mha areas and contributing about 40% to national food grain production. Rice residue management in combine harvested fields, for wheat sowing, is performed primarily through intensive tillage. This demands more energy input leading to higher production cost and lesser benefit-cost ratio. Indian government is promoting rotavators for speedy seedbed preparation in rice-wheat system. No-till wheat sowing is also quite popular amongst the farmers. This study compares energy input and benefit-cost ratio of six treatments viz. T_1 (RM_1 x 2 + sowing), T_2 (RM_2 x 2 + sowing), T_3 (RM_3 x 2 + sowing), T_4 (RM_4 x 2 + sowing), T_5 (No-till sowing) and T_6 (Disc harrow x 6 + Planking x 2 + sowing). Result revealed maximum time and fuel consumed in T_6 (10.13 h/ha and 59.85 l/ha) and minimum for treatment T_5 (1.39 h/ha and 6.19 l/ha). Energy saving was maximum (89.57%) in no-till wheat sowing (T_5) followed by rotavator treatments (47.08-62.65%) compared to treatment T_6. The energy productivity was highest (13.06 kg/MJ) for no-till sowing (T_5). It ranged from 2.73-4.20 kg/MJ for rotavator treatments (T_1-T_4) and was minimum (1.59 kg/MJ) for T_6. The benefit-cost ratio was found 2.99 for treatment T_6 and 6.35% higher for no-till wheat sowing (T_5). It ranged from 2.91-3.53 for treatments (T_1-T_4). Based on the results, T_5 was found most energy efficient treatment followed by T_3, T_4, T_2 and T_1. Conventional method (T_6) was found to be most energy intensive method of wheat establishment.

Keywords: Energy requirement, rotavator, wheat establishment, cost of production, no-till

INTRODUCTION

Agriculture has been the life line of Indian economy and provides livelihood to about 65% of the total population. It has largest arable land (160 Mha) sharing 11.2 percent arable land of the world. Rice-wheat are major crops grown in Indo-Gangetic Plains (IGP) covering around 10 Mha area and contributing about 40% of the country's total food grain production. During

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2014-15, these two crops together contributed more than 76% to the total food grain production of the country (Anonymous, 2016). In regions where lowland rice is cultivated during the rainy season, tillage operation for preparing seedbed for wheat sowing, in combine harvested rice fields, is considered most difficult and time-consuming. Conventionally farmers, in tarai region of Uttarakhand, use 6-8 operations, sometimes even more, of disc harrow followed by planking twice to prepare the seedbed for wheat sowing in combine harvested rice fields. This not only increases cost of cultivation but also results in delayed sowing and marginalize benefit-cost ratio. No-till technique or reduced tillage could help the farmers in earning more profit from the same land by reducing the cost of cultivation. No-till wheat sowing, introduced during 1995 (Singh and Singh, 1995), is now limited to progressive farmers of this region. It has been reported to save operational energy and cost of cultivation over traditional method (Sharma et al., 2007).

Rotavators (rotary tillers) have been reported to produce smaller clod-mean-weight diameter, better residue incorporation as well as most energy and cost effective for seedbed preparation (Singh, et al., 2006; Prasad, 1996). These are being promoted by Indian government by providing 50% subsidy to the farmers on its purchase. Due to government support and demand by the farmers, a large number of manufacturers are manufacturing and supplying various sizes of rotavators. However, the data on energy requirement by various sizes of rotavator is lacking. Considering this in view, study was undertaken to assess energy input and economics for various sizes of rotavators, conventional and no-till system of wheat establishment.

MATERIAL AND METHODS

The experiment was conducted at University Farm in combine harvested rice field for consecutive two years (2013-14 and 2014-15). Four sizes of rotavators with rotor lengths as 115, 148, 172 and 195 cm fitted with L-shape blades were selected for seedbed preparation whose technical details are presented in Table 1. On an average, the initial residue load was 6.03 t/ha with average height of stubbles as 36.19 cm. The initial soil moisture ranged from 23.2-25.8%. An area of 1.25 ha was selected and was divided into 18 equal plots (size 60 m x 10 m) to accommodate all the 6 treatments (Table 2) with three replications. In conventional method of seedbed preparation (T6), double action trailed type disc harrow (8 x 8 disc) with disc diameter as 610 mm and weighing 500 kg was used. A wooden plank, 300 cm long weighing about 65 kg, was used for clod crushing and levelling of the field. No-till ferti-seed drill (11 rows) was used to sow wheat, at 110 kg/ha seed rate, in all the treatments including T5. A tractor of 37.3 kW was used for operating the various implements. Other cultural practices, after sowing, were performed similar in all the treatments to minimize experimental variation. The data related to soil, machine and crop parameters were determined as per the standard procedures. Energy as well as economic analysis was made by adopting the standard methods and energy equivalences

(Kumar, 2013; Asodiya, 2014 and Anonymous, 1970). The data was analyzed using Completely Randomized Design (CRD).

Table 1: Specifications of various sizes of rotavator

Machine Parameters		RM_1	RM_2	RM_3	RM_4
Overall	Length, cm	142	181	195	225
	Width, cm	90	65	95	90
	Height, cm	115	115	115	115
Length of rotor shaft, cm		115	148	172	195
Number of flange		6	6	7	9
Number of blades per flange	On first flange	3	6	6	3
	On other flanges	6	6	6	6
	On last flange	3	6	6	3
Total number of blades		30	36	42	48
Rotor radius, cm		19.50	19.50	20.50	18.75
Width of blade, mm		90	85	80	85
Length of the blade, mm		280	280	280	285
Weight, kg		394	416	445	448

Table 2. Details of the treatments used for the study

Treatments	Description	Number of replications
T_1	RM_1 x 2 + sowing	3
T_2	RM_2 x 2 + sowing	3
T_3	RM_3 x 2 + sowing	3
T_4	RM_4 x 2 + sowing	3
T_5	No-till sowing	3
T_6-control	Disc harrow x 6 + Planking x 2 + sowing	3

RM1…4 represents the four sizes of the rotavators

RESULTS AND DISCUSSION

The results of clod size and residue incorporation has been presented in Table 3 which revealed minimum clod mean-weight-diameter (CMWD) of 14.9 mm in treatment T1 followed by 15.8, 16.7 and 17.2 mm in treatments T4, T3 and T2. Largest clod size of 17.6 mm was observed in case of treatment T6 (control). Smaller size of clods in treatments T1-T4 may be due to better slicing action by the rotavator blades as compared to discs of disc harrow. The clod size for all the treatments varied significantly from each other at 5% level of significance. Maximum residue incorporation (87.56%) was found for T1 followed by 87.40% (T4), 86.40 (T2) and 85.74% (T3). Treatment T6 showed minimum, 80.63%, residue incorporation (Table 3). Higher residue incorporation in treatments T1-T4 might be due to better cutting (because of higher peripheral velocity of rotavators blades in case of active tillage tools) and mixing of residue by the rotavators blades. Another reason could be the blade orientation with respect to direction of travel that might have helped in cutting the residues into smaller pieces consequently better mixing with soil. In treatment T6, the peripheral speed of disc cutting edge remains same, as in case of passive tillage tools, as that of tractor forward speed resulting in poor slicing action and hence poor residue incorporation. The percentage residue incorporation in all the treatments was found to vary significantly from each other at 5% significance level.

Table 3: mean values of soil and machine parameters for various treatments

Treatments	CMWD, mm	Residue inco-rporation, %	Observed speed, km/h	Field capacity, ha/h	Time required, h/ha		
					tillage	sowing	total
T_1	14.9^a	87.56^a	4.36	0.44	4.53	1.39	5.92^a
T_2	17.2^b	86.40^b	4.14	0.54	3.71	1.39	5.10^b
T_3	16.7^c	85.74^c	4.23	0.68	2.96	1.39	4.35^c
T_4	15.8^d	87.40^d	4.33	0.79	2.52	1.39	3.91^d
T_5	-	-	4.21	0.72	-	1.39	1.39^e
T_6	17.6^e	80.63^e	5.65	0.81	8.74	1.39	10.13^f

Same letter – non-significant at 5%

Machine parameters namely speed of operation for rotavators, treatment t1-t4, was found in the range of 4.14 - 4.36 km/h showing very little variation (table 3). This was due to the fact that the tractor was operated at the same forward speed to minimize the experimental variations. The speed of operation for disc harrow and planker in treatment t6 was comparatively higher which was probably due to lesser draft requirement. However, all the implements were operated within their recommended speed of operation. The field capacity, amongst the treatments t1-t4, was found maximum for t4 and minimum for treatment t1 which is obvious (table 3) as known that field capacity is a function of width of cut and speed of operation of an implement. Similarly field capacity was found more for disc harrow (0.81 ha/h) and planker (1.48 ha/h) which was again due to higher width and speed of operation.

Time required in various treatments revealed maximum time requirement of 10.13 h/ha (table 3) for conventional method of tillage and sowing (t6). This was due to more number of disking and planking operation. No-till method of wheat sowing (t5) recorded minimum time of 1.39 h/ha which was due to elimination of seedbed preparation. In treatments t1-t4, the minimum time requirement of 3.91 h/ha was recorded for treatment t4 in which largest size of rotavators was used. It was followed by treatments t3, t2 and t1 respectively. This was due to the fact that smaller rotavator would require more time to till a given area than a larger size of rotavator. Also the field capacity, ha/h, is inversely proportional to time requirement (h/ha). Almost similar pattern was observed for cumulative fuel consumption, l/ha, in various treatments. This was again due to lesser time requirement by a larger size of implement and vice-versa. Statistical analysis indicated significant variation in total time requirement for various treatments at 5% significance level.

The fuel consumption for each treatment was determined (table 4) which revealed minimum fuel consumption of 6.19 l/ha in t5 which is due to elimination of seedbed preparation. Treatment t6 consumed maximum diesel fuel which is due to repeated operation of disc harrow and planker. Among rotavator treatments, treatment t1 consumed more fuel followed by t2, t4 and t3 which is due to more time required in seedbed preparation. Statistical analysis shows that fuel consumption in each treatment vary significantly from each other at 5 percent significance level.

Table 4: mean values of soil, machine and crop parameters for various treatments

Treat-ments	Fuel consumption, l/ha			Number of plant / m^2	Average plant height, cm	Grain yield, q/ha	Straw yield, q/ha
	Tillage	Sowing	Total				
T_1	25.44	6.19	31.63^a	322	51	49.09^a	75.09
T_2	21.61	6.19	27.80^b	328	48	51.24^b	78.32
T_3	15.60	6.19	21.79^c	308	50	46.76^c	70.61
T_4	16.13	6.19	22.32^d	369	51	53.20^d	84.59
T_5	-	6.19	6.19^e	314	50	46.25^{ec}	70.66
T_6	53.66	6.19	59.85^f	319	49	54.09^f	83.85

Fuel consumption for various sizes of rotavators (T_1-T_4) was also determined on the basis of per meter rotor length and unit volume of soil worked and same is presented in Fig. 1 which indicated minimum fuel consumption (3.08 l/h) for treatment T_3 followed by T_4 (3.28 l/ha), T_2 (3.93 l/ha) and T_4 (4.90 l/ha). Fuel consumption, on the basis of unit volume of soil worked, also followed the similar trend. This indicated superiority of the rotavator used in treatment T_3 over other rotavators. In other words, rotavator with rotor size of 172 cm performed better than other three rotavators in respect of fuel consumption. This may also be due to the fact that the rotavator with rotor length of 172 cm was a better match, as compared to other rotavator size, for the size of tractor being used for operating it.

Wheat yield and its attributes has been presented in Table 4 which revealed that number of plants/ m^2 was observed highest (369) for treatment T_4 followed by treatments T_2, T_1, T_6 and T_5. The same was found minimum (308) for T_3 treatment. The plant height ranged between 48 and 51 cm for all the treatments under the experiment. The result also indicated maximum wheat yield of 54.09 q/ha under treatment T_6. It was observed as 53.20, 51.24, 49.09, 46.76 and 46.25 q/ha for treatments T_4, T_2, T_1, T_3 and T_5 respectively. The yield result for various treatments was found to vary significantly from each other at 5% significance level, however, yields of treatments T_3 and T_5 did not vary significantly. The higher yield in T_6 may be due to the higher weight of grains per ear head. The straw yield was observed maximum as 84.59 q/ha for treatment T_4 followed by treatments T_6, T_2, T_1, T_5 and T_3 respectively.

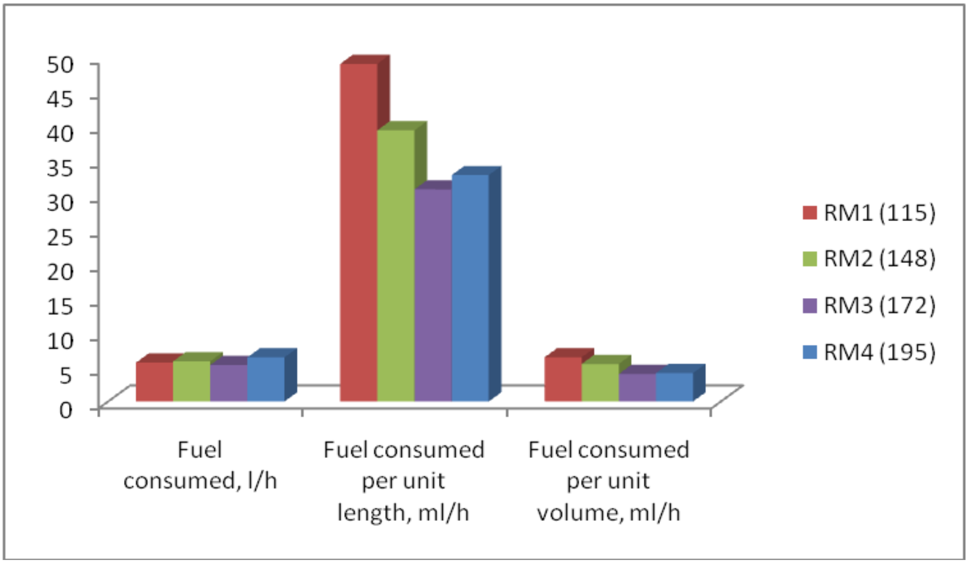

Figure 1. Fuel consumed by various sizes of rotavators

Energy analysis was performed for all the treatments and same has been presented in Table 5 that showed minimum total direct input energy (tillage +sowing operation) of 0.35 GJ/ha for treatment T_5 indicating as most energy efficient treatment. Amongst the rotavator treatments (T_1-T_4), input energy was observed minimum for treatment T_3 as 1.24 GJ/ha. Treatments T_4, T_2 and T_1 consumed 2.34, 27.45 and 45% more energy respectively compared to T_3 which was due to more time and fuel requirements in tillage operation because of comparatively smaller rotor length. Conventional method (T_6) recorded maximum, 174% higher, input energy as compared to treatment T_3. The energy saving, in terms of treatments T_6, was observed highest (89.57%) for treatment T_5 followed by treatments T_3, T_4, T_2. Minimum saving in input energy (47.08%) was observed for treatment T_1. The energy output to input ratio revealed minimum (45.95) for treatment T_6 and maximum 373.80 for treatment T_5 (no-till sowing). The total energy input and energy input-output ratio varied significantly for all the treatments at 5% level of significance. The energy productivity was also observed maximum (13.06 kg/MJ) for treatment T_5 followed by treatments T_4, T_3, T_2 and T_1. Treatment T_6 recorded lowest energy productivity of 1.59 kg/MJ. The statistical analysis indicated significant difference among the values of various treatments, however, treatment T_1, T_2 and T_2, T_3 and T_4 did not vary significantly among themselves at 5% level of significance.

Table 5. Energy input and output for various tillage treatments

Treatments	Human energy, MJ/ha			Fuel energy, GJ/ha	Total input energy, GJ/ha	Energy saving over T_6, %	Energy output, GJ/ha			Energy input-output ratio	Energy productivity, kg/MJ
	tillage	sowing	total				From grain	From straw	Total		
T_1	8.88	5.45	14.33	1.78	1.80[a]	47.08	71.08	69.46	140.54	78.28[a]	2.73a
T_2	7.27	5.45	12.72	1.57	1.58[b]	53.48	74.20	72.45	146.64	92.92[b]	3.25[ba]
T_3	5.80	5.45	11.25	1.23	1.24[c]	63.50	67.71	65.31	133.02	107.43[c]	3.78[cb]
T_4	4.94	5.45	10.39	1.26	1.27[d]	62.65	77.03	78.25	155.28	122.53[d]	4.20[db]
T_5	0.00	5.45	5.45	0.35	0.35[e]	89.57	66.97	65.36	132.33	373.80[e]	13.06[e]
T_6	17.13	5.45	22.58	3.37	3.39[f]	-	78.32	77.56	155.88	45.95[f]	1.59[f]

Economic analysis was performed for all the treatments included in the experiment (Table 4). The cost of cultivation was observed highest (451.57 USD/ha) for treatment T_6 which is 23.04% higher compared to T_5 which recorded minimum (367.01 USD/ha) input cost for cultivation.

Table 4. Economic analysis for various treatments

Treatment	Total input cost, USD/ha			Total return, USD/ha				B:C ratio
	Cost of tillage and sowing (A)	Other inputs cost (B)	Total input cost (A+B)	From wheat grain	From straw	Total return	Net profit	
T_1	56.41	354.51	410.92[a]	1105.79	521.30	1627.10	1216.18[a]	2.96[a]
T_2	49.42	354.51	403.92[b]	1154.22	543.73	1697.95	1294.03[b]	3.20[b]
T_3	40.42	354.51	394.92[c]	1053.31	490.20	1543.51	1148.59[c]	2.91[a]
T_4	39.40	354.51	393.91[dc]	1198.38	587.26	1785.63	1391.72[d]	3.53[c]
T_5	12.51	354.51	367.01[e]	1041.82	490.55	1532.37	1165.36[e]	3.18[bd]
T_6	97.06	354.51	451.57[f]	1218.42	582.12	1800.54	1348.98[f]	2.99[a]

1USD = 67.70 INR

Amongst rotavator treatments (T_1-T_4), T_4 and T_3 were having almost same cost of cultivation. Treatments T_1 and T_2 recorded marginally higher, 4.32 and 2.54%, cultivation cost compared to treatment T_3. Cost of cultivation for treatment T_4 was found 14.64% less compared to T_6.

This was mainly due to more time and fuel consumption per unit area basis. The net profit was observed highest for treatment T_4 followed by T_6, T_2, T_1, T_5 and T_3 respectively.

The statistical analysis indicated significant variation for all the treatments at 5% significance level. The benefit-cost ratio was found maximum (3.53) for treatment T_4 followed by T_2 (3.20), T_5 (3.18), T_6 (2.99), T_1 (2.96) and T_3 (2.91) respectively. Treatment T_4 resulted in 18.06% and 11.01% higher benefit-cost (B: C) ratio compared to treatment T_6 and T_5 respectively.

The statistical analysis indicated significant difference between the treatments T_1, T_2, T_4 and T_5, however, it did not vary significantly for rest of the treatments at 5% significance level.

CONCLUSIONS

In terms of direct energy requirement, T5 (no-till sowing) was found most energy efficient treatment for wheat establishment. Among rotavator treatments (T1-T4), treatment T3 and T4 showed similar result and were found energy efficient next to T5. The energy productivity was found again higher for T5, T4 and minimum for treatments T1, T6. B:C ratio was found higher for T4 followed by T2 and T5 treatments. Based on study, it is concluded that larger size of rotavator (195 cm rotor length) could be used as a substitute to conventional method of wheat establishment. Amongst all the treatments, no-till is most energy efficient method of wheat cultivation.

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