Effect of Selected Parameters on Field Performance of Rotary Tiller

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Preparation of an optimum seedbed condition by minimizing the time, cost and energy requirements has assumed considerable significance for the paddy-wheat farming system widely practiced in northern part of India. In order to study the effect of various parameters on the performance under actual field conditions, a rotary tiller was selected. Two types of the blades, namely, L-type and C-type were used. The rear shield position was adjusted at full down and full up positions and two different rotor speeds 185 rpm and 210 rpm were used for the study. The studies were conducted under four different field conditions, namely, manually and combine harvested paddy and wheat fields. It was found that the draft (negative) for the two types of blades L-shaped and C-shaped, decreased (163 kg_f to 63 kg_f) as the rotor speed increased (185 rpm to 210 rpm) for the shield kept in the lowered (down) position. While operating the rotary tiller (rotavator) under different field conditions, it was observed that at a given rotary speed, the rotary power requirement of C-shaped blades was 19% less as compared to L-shaped blades. But C-shaped blades required 13% less power because draft was about two and a half times more due to reduction in the rotor thrust. The power requirement of 24.2 kW was found to be the highest while operating the rotavator in the combine harvested paddy fields. Soil break up resulting from the action of L-shaped and C-shaped blades under selected field conditions was the lowest at 210 rpm of rotor speed while operating the rotavator in manually harvested wheat fields. The extent of residue incorporation was the maximum (99%) while operating the rotavator with the shield in the lowered position for both types of blades and at both rotor speeds studied.

Keywords: Rotavator; Rotary tiller; Tillage; Seedbed preparation

INTRODUCTION

Tillage is the most important primary activity for crop production. The cost and the timeliness of operation assume critical importance while deciding the type of tillage tool(s) and operations to be carried out. Surface tillage farming systems, such as, those using the traditional tools like ploughs and harrows are not very effective in mixing the stubbles of the preceding crop in the soil. Following this, the secondary tillage is done by using the cultivators, plankers etc. This practice is followed in most of the northern states of India, including Punjab, Haryana and UP, where wheat-paddy rotation is in vogue. The time between harvesting the first crop and sowing of the next crop is quite limited, keeping in view the tillage operations, irrigation and manpower availability. During the course of preparing a satisfactory seedbed for the next crop, the primary and secondary tillage operations require as many as 2 to 3 diskings, 2 to 3 operations of the field cultivator and 1 to 2 plankings. To minimize the time, cost and energy requirements for field operations, considerable attention is now being focused on the use of multi-powered tillage tools.

Rotary tools, which obtain their energy in more than one manner, reduce the draft requirements and have greater versatility in manipulating the soil to obtain the desired results. Thus, rotary power tillage systems also reduce the time required to get an optimum seedbed by combining the primary and secondary tillage operations. This allows the farmer to increase his farm acreage which becomes less dependent on hired farm labour, performs operations more timely and obtains higher yields[1]. The farmers are increasingly accepting the horizontal rotary tillage system or rotary tillers because they have low or negative draft requirements and produce high pulverization[2]. Also, if utilizing part of the tractor power through non-tractive means could reduce draft requirements, the tractor could be made lighter which would reduce its cost and soil compaction. In a study conducted by Bukhari, *et al*[3], it was found that the degree of soil pulverization attained by the rotary tiller was comparable with the use of a mould board plough, and harrow (twice) and spiked tooth harrow. Hence, the rotary tilling machines, in principle are capable of replacing the conventional system of using passive soil working tools.

Kosutic, *et al*[4] studied the energy requirements of rotary cultivators with two blades arrangement (flat and steep spiral) and two blade shapes (L-shaped and straight blade). It was concluded that the blade shape had greater influence on energy requirement than the arrangement of blade. Straight blade required 21.2% to 25.7% less energy than the L-blade. Forward speed and depth of tillage also influenced the energy requirement. Increasing the velocity from 0.68 m/s to 1.40 m/s decreased the energy requirement per unit volume of tilled soil by 23%. While increasing the depth of tillage by 40%, it

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decreased the energy requirement per unit volume of tilled soil by 19.3%. Salokhe, *et al*[5] investigated the effect of blade type on power requirement of a tractor drawn rotary cultivator during puddling in Bangkok clay-soil. The L-shaped blade attachment required 33%, 24% and 14% while the L and C combination blade attachments required 14%, 12% and 4% higher power than the C-shaped blade attachment during pass one at 1 km/h, 1.5 km/h and 2.0 km/h forward speed, respectively. The power consumed decreased at higher passes for all the blades.

Therefore, a study was planned to investigate the effect of blade type, rotary speed, rear shield position and forward speed on the performance of the rotary tiller under different field conditions.

METHODOLOGY

A 6-flange, 1.2 m wide rotavator was selected for the study (Figure 1). For measuring the fuel consumption, an auxiliary fuel tank of 5 l capacity was mounted on the tractor just above and to the left of the fuel injection pump. This tank was connected to the main fuel line through a 'Y' joint, thereby ensuring that the tractor could be run on diesel fuel from either of the two tanks. During the field tests, the main fuel tank supply was shut down and supply from auxiliary tank was used. A field size of 2000 m^2 was selected for each experiment. The soil type of the selected fields was sandy loam. Two types of blade, namely, C-type and L-type were used. These were mounted on the fixed flanges of the rotavator. The inter-flange spacing on the rotor (228 mm) and the mounting of the blades (steep spiral) on the flanges were kept constant. For the experiments, two rotor speeds of the rotavator, 185 rpm and 210 rpm were used. For each rotor speed, two positions of rear shield namely, 'Up' and 'Down' were maintained and tractor was operated at 2.86 km/h and 3.57 km/h forward speed with engine rpm meter showing 2000 rpm. This was repeated for each field condition, *ie,* manually harvested and combine harvested fields both for the paddy and wheat crops.

The tractor was run idle for 15 min to attain the normal working temperature. Thereafter, the rotavator was used for

Figure 1 A view of tractor operated rotavator with C-type blades

Figure 2 A view of tractor operated rotavator while preparing the field for wheat sowing with shield in the raised position

field operation (Figure 2). During the course of operation, different observations, such as, forward speed of the tractor, fuel consumption, tyre slippage, width of cut, depth of cut, draft, time taken and number of stubbles buried under the soil were recorded. Soil samples for soil pulverization and moisture content were also taken. All the treatments were repeated thrice. Statistical analysis of data was carried out and the variance at 5% level was computed.

RESULTS AND DISCUSSION

Effect of Blade Type, Speed of Rotor, Shield Position and Forward Speed on Draft

Negative draft was observed for C and L-shaped blades at 2.86 km/h and 3.57 km/h forward speeds, for rear shield in up and down positions and for both the rotor speeds of 185 rpm and 210 rpm under all the four field conditions studied (Table 1). Higher negative draft was observed for the rotor speed of 185 rpm (47 kg_f to 197 kg_f) as compared to 210 rpm (26 kg_f to 193 kg_f) for both the blade types, forward speeds and rear shield positions. This could be explained by the fact that as λ (ratio of peripheral speed to forward speed) increased with the increase of ω (rotor speed) at a given forward speed, horizontal component of the force exerted by the blades mounted on the rotor increased. The L-shaped blades offered higher negative draft (126 kg_f to 197 kg_f) as compared to the C-shaped blades (26 kg_f to 97 kg_f) for the same field and machine conditions. This is evident from the fact that L-shaped blades consumed more fuel due to increased soil-metal friction (Table 2) and exerted higher force on the drawbar. For both the rotor speeds and L and C-shaped blades, 3.57 km/h forward speed and shield in the lowered position, higher values of negative draft (85 kg_f to 197 kg_f) were observed as compared to its working at 2.86 km/h forward speed (56 kg_f to 173 kg_f) with the shield in the raised position. This could be explained by the fact that forward speed 3.57 km/h and lower position of the rear shield for 185 rpm and 210 rpm rotor speed and L and C-blades consumed more fuel as compared to other combination. The average fuel consumption for L-type blade at rotor speed of 210 rpm was 6.2 l/h for shield in the raised position and 6.4 l/h for shield in the lowered position. Similarly, the average fuel consumption for C-type blade at rotor speed of 185 rpm was 5.7 l/h and 5.8 l/h for up and down shield positions, respectively. Also, it was observed that the average fuel consumption was higher (6.4 l/h) at rotor speed of 210 rpm as compared to 185 rpm (5.9 l/h). Fuel consumption for L-type blade varied from 5.8 l/h to 8.1 l/h (mean 6.9) at 210 rotor rpm and from 5.4 l/h to 7.3 l/h (mean 6.2) at 185 rpm under all field conditions. Similarly, fuel consumption for C-type blade varied from 5.1 l/h to 6.9 l/h (mean 6.1) at 210 rotor rpm and 4.6 l/h to 6.6 l/h (mean 5.6) at 185 rpm under all field conditions studied. Statistical analysis of data reveals that all the four factors namely, rotor speed, forward speed, blade type and rear shield position had a significant effect on draft (negative) at 5% level of significance. It was also observed that even the combined effect of rear shield position and blade type; forward speed and blade type; forward speed and rotor speed; and blade type and rotor speed had significant effect on draft.

Table 1 Effect of forward speed, rotor speed, C and L-type blades and rear shield position on draft (kg_f) under different field conditions

Field Condition	Forward Speed, km/h	Shield Position	Draft, kg_f			
			185 rpm		210 rpm	
			L-type	C-type	L-type	C-type
Manually harvested paddy fields	2.86	Up	170	64	165	58
		Down	147	45	134	27
	3.57	Up	188	95	183	91
		Down	162	69	155	54
Combine harvested paddy fields	2.86	Up	173	65	172	61
		Down	149	46	136	27
	3.57	Up	197	97	193	96
		Down	166	69	157	54
Manually harvested wheat fields	2.86	Up	174	65	155	56
		Down	154	47	126	26
	3.57	Up	178	88	171	85
		Down	160	71	147	52
Combine harvested wheat fields	2.86	Up	176	66	162	58
		Down	156	47	128	26
	3.57	Up	182	90	180	89
		Down	164	72	149	52

Table 2 Effect of different parameters on fuel consumption (l/h) under different field conditions

Field Condition	Forward Speed, km/h	Shield Position	Fuel Consumption, l/h			
			185 rpm		210 rpm	
			L-type	C-type	L-type	C-type
Manually harvested paddy fields	2.86	Up	5.7	4.9	6.4	5.3
		Down	5.8	5.3	6.5	5.8
	3.57	Up	6.1	5.7	6.9	6.2
		Down	6.4	5.8	7.3	6.4
Combine harvested paddy fields	2.86	Up	6.4	5.4	7.1	5.9
		Down	6.5	5.8	7.3	6.4
	3.57	Up	6.8	6.2	7.6	6.7
		Down	7.3	6.6	8.1	6.9
Manually harvested wheat fields	2.86	Up	5.4	4.6	5.8	5.1
		Down	5.6	4.9	6.0	5.5
	3.57	Up	5.4	5.4	6.2	5.9
		Down	5.5	5.6	6.4	6.2
Combine harvested wheat fields	2.86	Up	6.1	5.1	6.5	5.7
		Down	6.3	5.5	6.8	6.1
	3.57	Up	6.4	6.1	6.8	6.4
		Down	6.9	6.3	7.2	6.7
Mean		Up	6.0	5.4	6.7	5.9
		Down	6.3	5.7	7.0	6.3

The crop residues for manually harvested paddy field was 63 q/ha and 73 q/ha for combine harvested paddy fields. So, there was higher value of draft (negative) for later field condition because of increased volume handled by the machine, which increased the fuel consumption and hence, the draft. Similarly, the value of crop residues for manually and combine harvested wheat field was 32 q/ha and 38 q/ha, respectively. The fuel consumption was the maximum for combine harvested paddy field (7.1 l/h to 8.1 l/h for L-type and 5.9 l/h to 6.9 l/h for C-type blades) at 210 rotor rpm because of higher soil density (1.49 g/cm^3) as compared to wheat harvested field (1.31 g/cm^3). The fuel consumption was the lowest for manually harvested wheat fields (5.1 l/h to 6.3 l/h for C-type and 6.1 l/h to 6.9 l/h for L-type blades).

Effect of Different Parameters on Rotary Power Requirements

The power requirement (Table 3) was lower for rotor speed of 185 rpm (6.8 kW to 20.6 kW) and higher for rotor speed of 210 rpm (8.9 kW to 24.2 kW). This was true for the blade types, forward speeds and rear shield positions. The higher power requirement at higher rotor speed, *ie,* at 210 rpm, could be explained by the fact that increasing λ (bite length) by increasing ω resulted in greater acceleration of soil particles, which resulted in higher velocity of soil particles that increased the throw and impact against the shield cover. For higher values of λ the number of succeeding blades, which passed through the undisturbed soil cross-section increased and there was accelerated crushing, re-circulation and displacement of the soil-mass. That is why at rotor speed of 210 rpm, more fuel was consumed as compared to 185 rpm (Table 2). The power requirement for a given rotor speed was lower for the C-shaped blades (6.8 kW to 19.0 kW) and higher for the L-shaped blades (10.3 kW to 24.2 kW). This was true for all the variables studied as better (increased) soil break up resulted from the action of the L-shaped blades (Table 4). The power requirement was lower for C-shaped blades when operated at forward speed 2.86 km/h and rear shield in the

Table 3 Power requirement of rotary tiller (kW) at different forward speeds, rotor speeds, rear shield position and C and L-type blades under different field conditions

Field Condition	Forward Speed, km/h	Shield Position	Power Consumption, kW			
			185 rpm		210 rpm	
			L-type	C-type	L-type	C-type
Manually harvested paddy fields	2.86	Up	11.5	8.1	14.8	9.8
		Down	12.3	9.7	15.3	12.0
	3.57	Up	15.3	13.4	19.1	15.5
		Down	16.8	13.8	20.9	16.5
Combine harvested paddy fields	2.86	Up	14.6	10.2	18.0	12.6
		Down	15.4	12.3	18.9	14.8
	3.57	Up	18.3	15.8	22.0	17.8
		Down	20.6	17.5	24.2	19.0
Manually harvested wheat fields	2.86	Up	10.3	6.8	12.2	8.9
		Down	11.1	7.9	13.1	10.5
	3.57	Up	12.2	12.0	15.8	14.4
		Down	12.7	12.8	16.6	15.6
Combine harvested wheat fields	2.86	Up	13.4	8.8	15.3	11.4
		Down	14.4	10.5	16.5	13.5
	3.57	Up	16.3	15.2	18.1	16.6
		Down	18.7	16.1	20.1	17.9

Table 4 Effect of rotor speed, forward speed, blade shape and different positions of rear shield on mean mass diameter (mm)

Field Condition	Forward Speed, km/h	Shield Position	Mean Mass Diameter, mm			
			185 rpm		210 rpm	
			L-type	C-type	L-type	C-type
Manually harvested paddy fields	2.86	Up	2.2	2.3	1.9	2.2
		Down	1.8	2.1	1.7	2.2
	3.57	Up	2.4	2.7	2.3	2.4
		Down	2.0	2.3	2.0	2.3
Combine harvested paddy fields	2.86	Up	2.2	2.5	1.9	2.3
		Down	1.8	2.1	1.7	2.0
	3.57	Up	2.4	2.7	2.3	2.4
		Down	2.0	2.2	2.0	2.3
Manually harvested wheat fields	2.86	Up	2.0	2.1	1.8	2.0
		Down	1.7	1.9	1.6	1.7
	3.57	Up	2.2	2.5	1.9	2.2
		Down	1.9	2.2	1.8	2.0
Combine harvested wheat fields	2.86	Up	2.1	2.2	1.8	2.0
		Down	1.7	2.0	1.6	1.7
	3.57	Up	2.2	2.5	2.0	2.2
		Down	1.9	2.2	1.8	2.0

raised position (8.1 kW to 12.6 kW) as these blades (C-shaped) consumed less fuel as compared to the L-shaped blades (10.3 kW to 18.0 kW) for the same experimental conditions. The L-shaped blades cut the soil slice off almost entirely along the cycloid and one of the lateral planes along the full depth of the blade. The C-shaped blades partly cut and partly tore the soil slice along the cycloid; but the slice of the soil was cut off entirely along all its lateral planes but at varying depths. Therefore, in the cutting of the soil by the C-shaped blades, the lateral planes of varying depths were observed instead of the entire depth of the lateral plane as in the case of L-shaped blades. In the raised positions of the rear shield, there was lower power consumption as there was less throwing and crushing of the clods against the shield by the rotary tiller. The maximum power consumed was 24 kW for combine harvested paddy field at 3.57 km/h forward speed for lowered rear shield at 210 rpm rotor speed. The C-shaped blade required about 19% less PTO power than L-shaped blade. But C-shaped blades required 13% less total power because the draft was about two and a half times more in the case of the C-shaped blade due to the reduction in the rotor thrust. Statistical analysis of data reveals that all the four factors namely, rotor speed, forward speed, blade type and rear shield position had a significant effect on the power consumption of the rotary tiller operation at 5% level of significance.

Effect of Various Parameters of Rotary Tiller on the Soil Break Up

The rotor speed of 210 rpm led to finer soil break up (1.6 mm to 2.4 mm) as compared to 185 rpm (1.7 mm to 2.7 mm) because of the shorter bite length and greater acceleration of soil particles against the rear shield as well as due to additional impact and re-circulation of the soil particles (Table 4). The action of the L-shaped blade led to the finer soil break up (1.6 mm to 2.4 mm) as compared to the C-shaped blades (1.7 mm to 2.7 mm) for 185 rpm and 210 rpm rotor speeds. Also, for the L-shaped blade, forward speed of 2.86 km/h and rear shield in the lowered position resulted in the maximum soil break up (1.6 mm to 1.8 mm). In other words, higher rotor speed, lower forward speed and lowered position of rear shield catered to higher soil break up but also required more power. This was due to the fact that the number of succeeding blades, which passed through the undisturbed soil cross-section, increased and there was accelerated crushing, re-circulation and displacement of soil mass that resulted in finer soil break up. The variation in the degree of soil break up within the fields could be ascribed to the difference in the amount of straw and crop residue handled during the course of operation of the rotavator as well as to the differences in the soil bulk densities of the paddy and wheat fields. Rotor speed, forward speed, blade type and rear shield position had a significant effect on clod size at 5% level of significance.

Effect of Field, Machine and Operational Parameters on Residue Incorporation

The extent of residue incorporation was 89.0% to 98.7% for the rotor speeds, blade shapes, forward speeds and rear shield positions studied (Table 5). It was observed that there was thorough mixing of the crop residues with the soil cut by the rotary tiller and a fairly high percentage of the same was buried under the soil for subsequent decomposition. The lowered position of the rear shield of the rotavator led to

Table 5 Effect of forward speed, blade type, rotor speed and shield position on residue incorporation (%) under different field conditions

Field Condition	Forward Speed, km/h	Shield Position	Residue Incorporation, %			
			185 rpm		210 rpm	
			L-type	C-type	L-type	C-type
Manually harvested paddy fields	2.86	Up	98.6	97.2	97.3	98.6
		Down	98.6	98.7	98.7	98.7
	3.57	Up	97.3	97.3	97.2	97.2
		Down	97.3	97.2	98.6	97.3
Combine harvested paddy fields	2.86	Up	94.4	93.1	93.2	95.7
		Down	97.3	97.2	98.7	97.2
	3.57	Up	94.4	93.2	95.8	93.0
		Down	95.8	97.1	98.6	97.3
Manually harvested wheat fields	2.86	Up	94.9	96.4	95.7	94.9
		Down	96.4	97.1	97.1	97.8
	3.57	Up	96.4	93.4	95.7	95.7
		Down	97.8	96.3	97.8	97.1
Combine harvested wheat fields	2.86	Up	90.6	92.2	91.4	90.5
		Down	92.1	92.8	93.6	93.5
	3.57	Up	92.0	89.0	91.4	91.3
		Down	92.8	92.0	93.4	92.7

comparatively better results (92.1% to 98.7%) as compared to the raised position of the shield (89.0% to 98.6%). This could be explained by the fact that for the lowered position of the rear shield higher impact and crushing of the clods against the rear shield and better chopping and incorporation of the crop residue occurred for all the field conditions studied. Soil inversion varied from 97.2% to 98.7% for C and L-type blades at 210 rpm rotor speed under manually harvested paddy fields (Table 5). In combine harvested paddy fields, soil inversion was 93.0% to 98.6% for both types of blades at 210 rpm. Similar results were obtained for the wheat harvested fields. In all cases, soil inversion was better in manually harvested fields as compared to combine harvested fields because of low crop residue handling. The difference in the weight of the crop residues or soil bulk density had little effect on the soil inversion. However, the mixing of the crop residues was better in case of paddy-harvested fields because of increased shearing, cutting and less friction of the paddy straw. Statistical analysis reveals that rotor speed, forward speed and blade type had no significant effect on the extent of residue incorporation by rotary tiller at 5% level of significance.

CONCLUSIONS

1. The C-shaped blades required about 19% less PTO power than the L-shaped blade. But the C-shaped blades required 13% less total power because the draft was about two and a half times more for the C-shaped blades due to reduction in rotor thrust.

2. Soil break up was comparatively better for the L-shaped blade (1.6 mm) at 210 rpm of rotor in the manually harvested wheat fields as compared to (2.0 mm) the combine harvested wheat fields.

3. The extent of residue incorporation was the maximum (99%) while operating the rotavator with the lowered position of the shield for both types of blades and for both the rotor speeds studied. It varied between 89% to 98% for L and C-type blades under different field conditions.

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