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Traction performance of different size of cage wheel for power tiller

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ABSTRACT

The selection of cage wheel is of primary importance in tillage operations for the optimization of traction performance. Selection of proper cage wheel helps in limiting slip and fuel consumption which involves energy loss and it also minimize time required for soil tillage. The present study aim to investigate the tractive and drawbar performance of different diameter of cage wheels. Three cage wheels of diameter 68 cm, 73 cm, and 78 cm with 30^0 lug angles were tested in four different water levels of 5 cm, 10 cm, 15 cm and 20 cm in wet land field conditions. Results shows that cage wheel of 73 cm diameter gave better performance in terms of higher tractive efficiency with less power consumption, than other cage wheels. Reducing the diameter of cage wheel increases the draft and sinkage and blocking of soil on lug surface. The maximum tractive efficiency was found in the range of 73-78% at 789 N to 1224 N draft and drawbar power was in the range of 505 W to 565 W.

Key words: *Draft, slippage, traction performance, wheel diameter*

INTRODUCTION

Power tiller is a walking type tractor which is popular among the farmers for easy handling and smooth farm operations. Cage wheel is a traction device which support the vehicle by distributing the weight of the machine over large contact area, reduce soil compaction and prevent it from bogging down (Soemengat, 1962). Pneumatic, rubber-tired wheels performed poorly in wet soil conditions and the power loss of these wheels was about 66% of the total loss. A study on the effect of the design parameters of cage wheel in soil bin showed that wheel with 680 mm diameter, 16 lugs and 220 mm lug width gave optimum dynamic performance (Nakashima and Tanaka, 1986). A pair of cage wheel was tested with a diameter of 93 cm and a width of 38 cm fitted to a 12.5 kW four-wheel (two-wheel drive) tractor in a flooded, puddled field and found that the 30° lug spacing with 12 lugs gave the highest power transmission (Jayasundera, 1980). In wet-land conditions, the cage wheel has been proved to be the most effective traction aid. Verma, 1984 revealed that cage wheel exerted 3 times more pull in comparison with tyres in flooded soil conditions. Numerous studies have been conducted in designing and testing of cage wheels for power tillers in puddled soft soils. These studies have concluded that a cage wheel design suitable in one soil condition might not perform well in other conditions. Conventional lug wheels, however, still have problems which could reduce their traction and flotation performances. Cage wheels using fixed lugs also have a soil blocking problem among the lugs when operated in paddy soil (Triratanasirichai et al., 1990). Although the soil adhesion plays a significant role for soil sticking on cage wheel lugs (Salokhe and Clough, 1988). A coating of lug surfaces with teflon tape, ceramic tile and enamel did not affect the lug forces. A research shows that when an open flat-lugged wheel for a small power tiller operated on agricultural soils the cross-sectional area of blocked soil (*i.e.,* amounts of soil wedge) became smaller with increase in lug angle (Triratanasirichai et al., 1990). A experiment was conducted to find out the effect of soil deformation and lug sinkage on the tractive performance of a lugged wheel and found that the reaction forces of a wheel vary as the deformation of the soil varies (Masuda and Tanaka, 1964). Gee-Clough and Chancellor, 1976 measured the lug forces developed by a single lug of a cage wheel in Maahas clay loam soil. It was observed that several parameters have a strong effect on the forces developed by a single lug of an open lugged wheel moving slowly within the soil. This study, therefore, aimed at investigating the effect of water levels on traction performance of power tiller with different diameter cage wheels in wet soil conditions.

MATERIALS AND METHODS

The experiment was conducted in Indira Gandhi Krishi Viswavidyalaya, Raipur research farm size of 70 x 20 m^2, three replication for three different diameters of cage wheel on different water level conditions were taken. There was wet clay soil on field and test was conducted on flooded condition. Power tiller of Greaves Ltd. of 4.85kW engine power was used in the experiment. Three cage wheels selected 73 cm diameter with 30^0 lug angle (C1), 68 cm diameter with 30^0 lug angle (C2), and 78 cm diameter with 30^0 lug angle (C3). All three diameter of cage wheel of C1, C2 and C3 were tested on different water level of 5, 10, 15 and 20 cm in wet land field and observations recorded were draft, traction performance, sinkage, and cone index of soil (Plate 1). A dynamometer was used to measure draft and cone penetrometer was used to measure soil strength.

Table 1. physical parameter of soil during the experiment.

S.N.	Particular	Parameters
1	Soil type	clay
	Particle size dist,	33
	Sand (0.05 - 2.0 mm)	10
	Silt (0.002 - 0.05 mm)	57
	Clay (> 0.002 mm	
3	Plastic limit %	24
4	Liquid limit%	47
5	Cone Index (kPa)	147

Tractive performance

Tractive performance is very important parameter which depends on soil properties, size of wheel, axle load, and speed of operation which is determinant of draft and drawbar power. Following parameters and formulae were used for calculation:

Axle power Pa = $[2\pi w\ Q]/60$ Watt

Drawbar power Dp = [P x V] Watt (Trip et al.,1995)

Tractive efficiency η = [Dp/Pa] x100 % (Ananto et al., 1998)

Wheel slip, (s) = $[(V_o - V)/V_o]$ X 100 % (Wijaya, 1992)

Where Pa is the axle power (W) and Q is the axle torque (N-m), η is the tractive efficiency. V_o is the theoretical forward speed (no-load) (m/s), V is the actual forward speed (with load) (m/s), w is the rotation

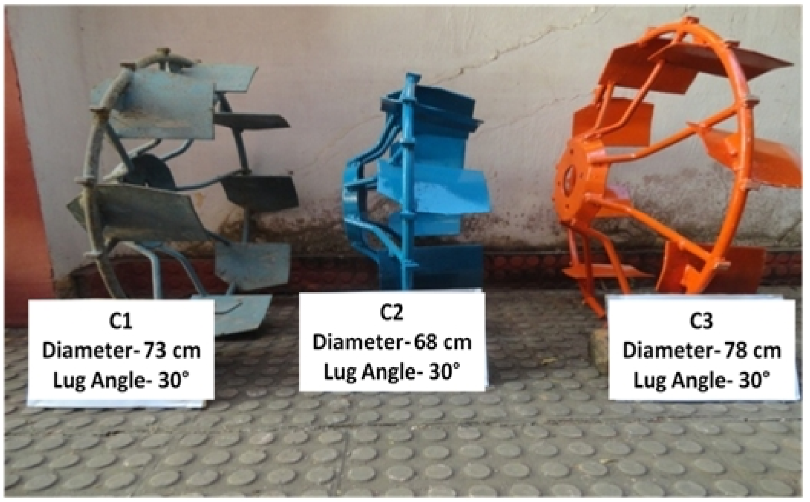

Plate 1. Different diameter of cage wheel used in the study.

of wheel tested (rpm), P is the drawbar pull generated (N), Dp is the drawbar power (W),

RESULT AND DISCUSSION

Effect of diameter on drawbar power and tractive efficiency at 0-5 cm depth of water

It was observed that in each cage wheel as draft increases drawbar power also increases (Fig. 1). Maximum draft was observed in cage wheel C2 due to its smaller diameter resulted in bogging down and more sinkage. The maximum drawbar power was 565.20 W at 1256 N draft for cage wheel C1 while 572.85W at 1273 N and 480.32 W at 1264 N draft for cage wheel C2 and C3, respectively. Tractive efficiency was found maximum for C1 (75.90%) followed by C3 (56.78%) and minimum for C2 (61.87 %). It was observed that as draft increases the tractive efficiency also increases till a point but further decreases for all cage wheels (Fig. 2). At 0-5 cm water level soil was muddy that creates problem of soil sticking results in increase of draft due to more slippage and sinkage. It was noticed that maximum draft was found with minimum tractive efficiency of cage wheel C2. While maximum tractive efficiency was found in cage wheel C1.

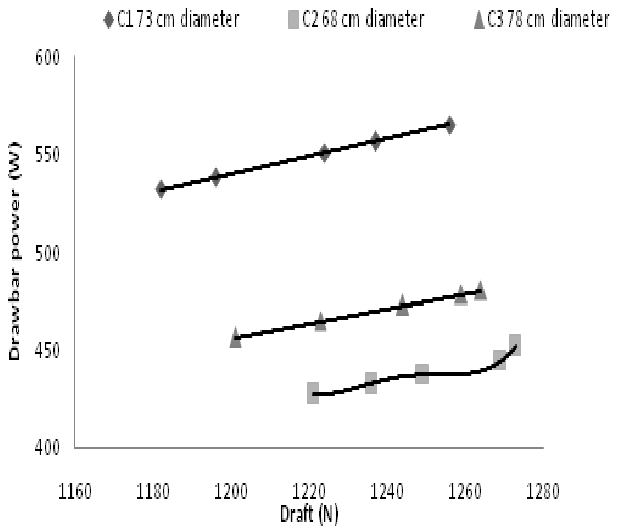

Fig. 1. Effect of draft on drawbar power at 0-5 cm depth of water.

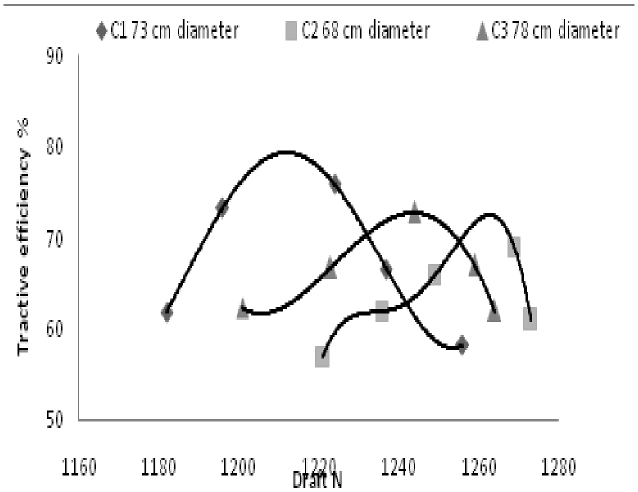

Fig. 2. Effect of draft on tractive efficiency at 0-5 cm depth of water.

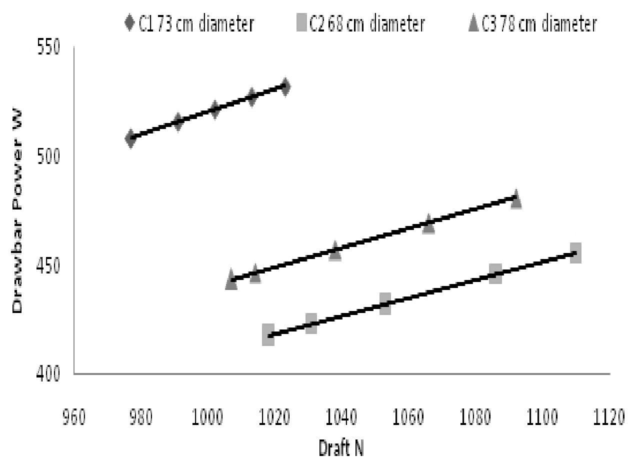

Fig. 3. Effect of draft on drawbar power at 5-10 cm depth of water.

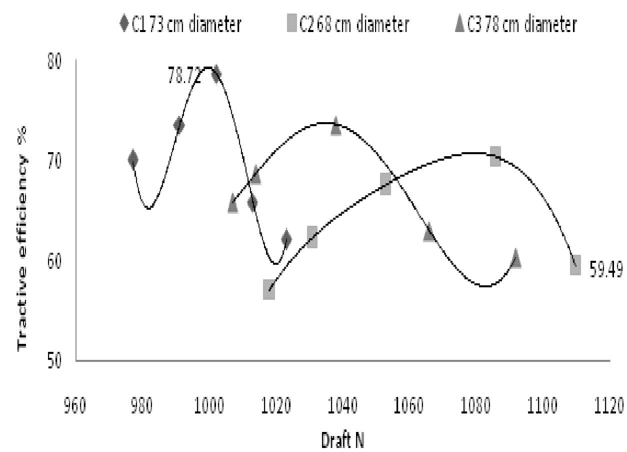

Fig. 4. Effect of draft on tractive efficiency at 5-10 cm depth of water.

Effect of diameter on drawbar power and tractive efficiency at 5-10 cm depth of water

Due to the smaller diameter of cage wheel C2 takes more sinkages, and sticking which resulted more draft as compare to the C1 and C3. The maximum drawbar power was observed 531.96W at 1096 N for C1 followed by C3, 480.48 W at 1092 N and minimum drawbar power was 455.10 W at 1110 N for cage wheel C2. It was observed that in each cage wheel as draft increases the drawbar power also increases (Fig. 3). Tractive efficiency was more at 5-10 cm depth of water as compare to the 0-5 cm of water level because lug plate of cage wheel cut the soil hence soil sticking reduces or washed by water and less sinkage. The maximum tractive efficiency was observed for cage wheel C1 with 78.72% with 9.80% wheel slippage and 4.8 cm sinkage. It was found that with increase in draft, the tractive efficiency was increased and the tractive efficiency was achieved 73.53% and 70.39 % for cage wheel C3 and C2 (Fig. 4). The lowest tractive efficiency was 59.49 % for C2 followed by 60.35% for C3 and 62.10 % for C1.

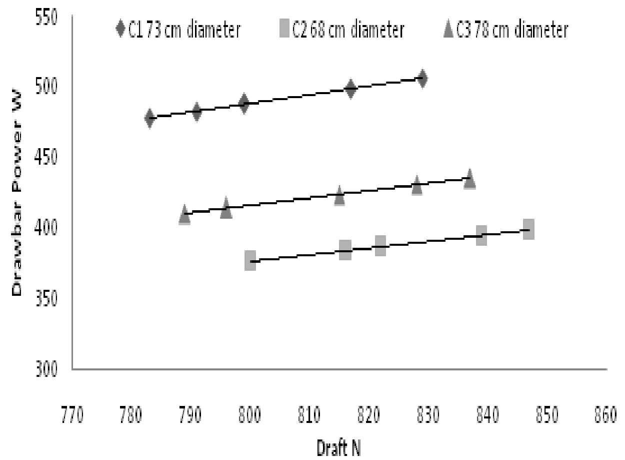

Fig. 5. Effect of draft on drawbar power at 10-15 cm depth of water.

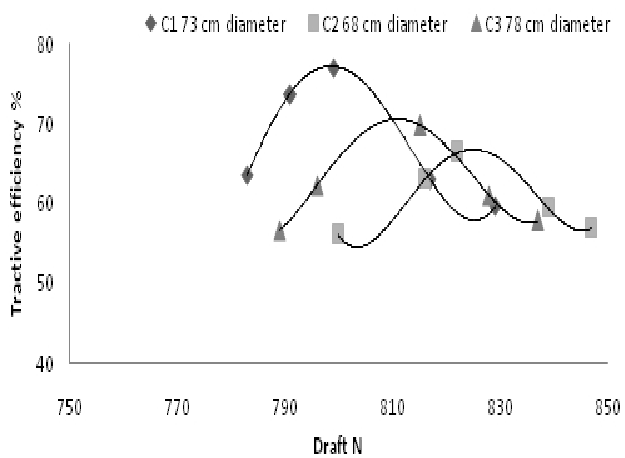

Fig. 6. Effect of draft on tractive efficiency at 10-15 cm depth of water.

Effect of diameter on drawbar power and tractive efficiency at 10-15 cm depth of water

The maximum drawbar power was obtained in C1 cage wheel of 505.69 W at 829 N draft than followed by C3, 435.24 W at 837 N and C2, 398.04 W at 847 N draft. It was found that with the increase in standing water level in wet land field drawbar power requirement reduces and draft requirement also reduces (Fig. 5). The minimum draft was obtained 376W at 800 N by cage wheel C2 and 410.28 W at 789 N for C3 while 477.63 W at 783 N draft for cage wheel C1. Tractive efficiency of different diameter of cage wheel is presented in (Fig. 6). It was observed that as standing water level increases tractive efficiency increases. The maximum tractive efficiency was observed in cage wheel C1 77.05 % at 799 N draft followed by 69.73 % at 813 N draft and 66.36 % at 822 N draft for cage wheel C3 and C2. It was noticed that as draft increases tractive efficiency increases up to certain point than further decreases for all three cage wheel. Minimum tractive efficiency was observed for cage wheel C2 56.01% at 800 N draft.

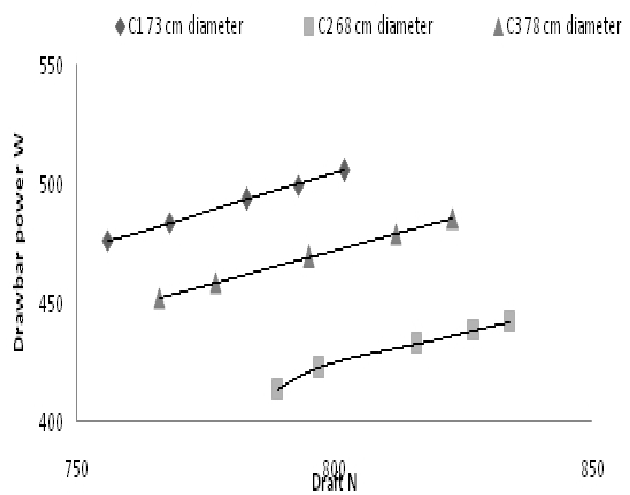

Fig. 7. Effect of draft on drawbar power at 15-20 cm depth of water.

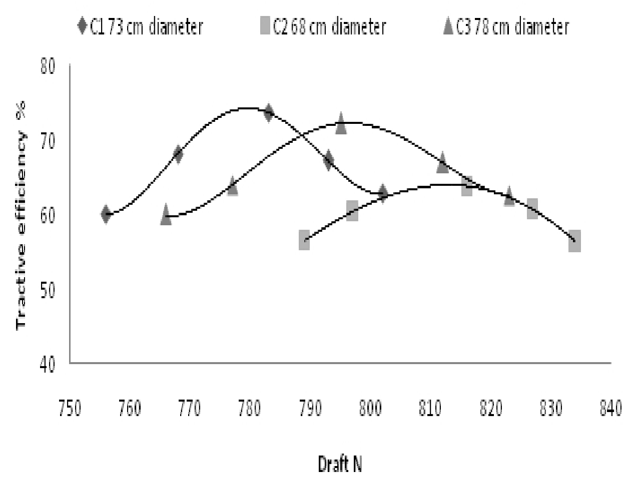

Fig. 8. Effect of draft on tractive efficiency at 15-20 cm depth of water.

Effect of diameter on drawbar power and tractiveefficiency at 15-20 cm depth of water

It was observed that smaller diameter of cage wheel gave the maximum draft 834 N with minimum drawbar power 412.87 W for cage wheel C2 followed by cage wheel C3 and C1 (Fig. 7). Maximum drawbar power was obtained 505.26 W for cage wheel C1 and 485.57 W, 442.02 W for C3 and C2, respectively. It was observed that with the increase in draft, tractive efficiency decreases. Maximum tractive efficiency was observed 73.71% at 493.29 N drafts for cage wheel C1 followed by 72.20% at 469.05N draft and 63.76% at 432.48% at 816N for cage wheel C3 and C2 respectively (Fig. 8). Minimum tractive efficiency was observed 56.44% for C2 and 59.97% and 60.10% for cage wheel C3 and C1, respectively.

CONCLUSION

With the increase in the diameter of cage wheel there was significant reduction of sinkage *i.e.,* 4.10 cm, 5.55 cm and 5.07 cm sinkage values for C3, C1 and C2 cage wheel. When lug sinkage increased from 2.5 to 4.5 and 6.5 cm, the peak pull force values increased by 1.5 and 1.8 times, respectively. With reducing the diameter of cage wheel draft forces increases due to sinking and sticking of soil over lug plates which causes lower tractive efficiency and it was observed maximum in C2 cage wheel. As the lug sink into the soil, the soil portion just below the lug tip was compressed and pulled forward by the cohesion effect as lug rotation increased. At the lower tip of the lug in all cases the soil was compressed and then sheared thus forming a trench in the soil mass. It was also observed that increasing water level reducing the draft and increasing tractive efficiency in all cage wheels due to less sinking and sticking of soil. Higher tractive performance observed 78.72% in 73cm diameter of cage wheel at 5-10 cm water level.

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