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Field evaluation of an electric motor powered tiller

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Abstract : An electric motor operated power tiller was developed and field evaluated. Field tests were conducted with 200, 250,300, 350 and 400 mm width of sweep blade fitted to the electric tiller at 20,40,60,80 and 100 mm depth of operation and at 1.05, 1.57,2.09 and 2.61 km h^{-1} forward speed. The tiller with 200 mm width of sweep blade at 80 mm depth and 1.05 km h^{-1} speed performed better with minimum wheel slip of 5.5 per cent and maximum field capacity of 7.4x 10^{-2} ha h^{-1}. The tiller costs Rs.20.000. Operational cost of the tiller for weeding was calculated to be Rs. 450 ha^{-1} as compared to Rs.2000 ha^{-1} for the manual method.

Key words : Power tiller, Electric tiller, Sweep, Green house equipment.

Introduction

Internal combustion engine operated power tillers are commonly used by small farmers in the developing countries like India for light tillage, weeding and inter culture, farm transport and allied agricultural operations. Electric motor operated tiller is a substitute to the engine operated power tiller. The eco-friendly electric motor powered tiller has minimum noise and vibration, no air pollution, needs minimum maintenance, simple in design, easy to start and easy to reverse. The electric tiller has good scope to be used in the green houses which are becoming popular now a days. There is scope to reduce energy expenditure in agricultural sector by using electric powered tillers instead of engine powered tillers (Latif and Christianson, 1987). Therefore an electric motor powered tiller was developed and field evaluated.

Materials and Methods

The electric tiller consisted of a single phase 1000 W, 6.1A continuous rating alternating-current (AC) induction motor, 420 mm diameter iron cage wheels, sweep blade, depth wheel, power transmission housing, handle and loose-belt clutch. Rotational speed of ground wheels to achieve 2.5 km/h^{-1} walking speed was calculated as 20 rpm (Tajuddin *et al.* 1992). Motor speed of 1440 rpm was reduced to 20 rpm in three steps with V-belt pulley (3:1) and sprocket -chain mechanisms (5:1 and 3:1). Wheel revolution counter and digital tachometer were incorporated in the tiller (Murugesan, 1998). The tiller was tested in sandy soil with 200 (B_1), 250 (B_2) 300 (B_3), 350 (B_4) and 400 mm (B_5) width of sweep blade, 20 (D_1) 40 (D_2), 60 (D_3), 80 (D_4) and 100 mm (D_5) depth of operation and 1.05 h^{-1} (F_1), 1.57 (F_2), 2.09 (F_3) and 2.61 km h^{-1} (F_4) forward speeds.

Results and Discussion

Power expended by the electric tiller with 200 mm sweep blade varied from 354 W at 1.05 km h^{-1} forward speed with 20 mm depth of operation to 1084 W at 2.61 km h^{-1} forward speed with 100 mm depth of operation (Table 1). The power consumption increased linearly in general with increase in forward speed. As the forward speed increased, draft did not vary much throughout the test. Draft increased with increase in depth of operation. Draft of the sweep blade varied from 118 to 853 N at all forward speeds tested.

The effective field capacity increased at decreasing rate with increase in forward speed and also decreased with increase in depth of operation. Slippage of wheel increased with forward speed and also with increased depth of operation. Wheel slip varied from 1.93 to 14.73 per cent through out the test, which revealed the suitability of the 200 mm sweep blade at all the operating forward speeds.

Power requirement of the electric powered tiller with 250 mm sweep blade linearly varied with increase in forward speed. Power requirement increased with increase in depth of operation. The electric tiller with 250 mm width sweep blade consumed 1096 W at 2.61 km h^{-1} forward speed at 100 mm operating depth. Draft of the sweep blade decreased with increased forward

Table 1. Field performance of electric motor powered tiller

Width of sweep blade (mm)	Forward speed (km h⁻¹)	20 mm EFC x 10^{-2} (ha h^{-1})	20 mm PC (W)	20 mm Draft (N)	20 mm Slip (%)	40 mm EFC x 10^{-2} (ha h^{-1})	40 mm PC (W)	40 mm Draft (N)	40 mm Slip (%)	60 mm EFC x 10^{-2} (ha h^{-1})	60 mm PC (W)	60 mm Draft (N)	60 mm Slip (%)	80 mm EFC x 10^{-2} (ha h^{-1})	80 mm PC (W)	80 mm Draft (N)	80 mm Slip (%)	100 mm EFC x 10^{-2} (ha h^{-1})	100 mm PC (W)	100 mm Draft (N)	100 mm Slip (%)
200	1.05	1.96	354	118	1.93	1.93	393	265	1.93	1.88	430	412	5.50	1.80	463	540	5.50	1.76	513	706	7.14
	1.57	3.14	432	118	3.85	2.95	500	265	5.50	2.89	570	432	7.14	2.76	638	598	8.75	2.65	716	814	11.84
	2.09	3.52	529	157	5.50	3.34	609	304	8.75	3.33	696	461	10.35	3.11	789	618	13.33	3.01	888	824	1333
	2.61	3.90	578	147	7.14	3.80	726	323	8.75	3.67	823	481	10.35	3.29	946	647	13.33	3.15	1084	853	14.73
250	1.05	2.36	357	137	3.85	2.32	413	314	5.50	2.21	433	422	10.24	2.08	468	598	13.33	2.07	518	834	18.75
	1.57	3.61	447	157	3.54	3.85	509	294	5.50	3.36	586	471	7.14	3.28	642	628	11.84	3.21	710	804	13.33
	2.09	4.01	531	157	7.69	3.84	620	314	9.02	3.68	713	471	10.34	3.63	793	628	16.13	3.54	900	844	18.75
	2.61	4.86	610	167	10.34	4.63	760	373	13.33	4.45	873	579	14.73	4.29	958	647	17.44	4.10	1096	863	18.67
300	1.05	2.99	363	167	3.85	2.95	422	373	7.14	2.88	439	461	11.84	2.74	520	746	13.33	2.68	553	863	18.75
	1.57	4.33	462	196	3.85	4.17	541	373	3.85	4.09	645	608	0.34	3.94	720	765	10.34	3.80	806	1039	13.33
	2.09	4.71	637	353	3.85	4.63	686	441	5.50	4.53	823	706	7.14	4.42	939	922	10.34	4.25	948	932	13.33
	2.61	5.68	628	196	7.69	1.55	786	412	7.69	5.41	959	647	10.34	5.03	1096	833	13.33	4.91	1253	1079	14.73
350	1.05	3.33	373	196	3.85	3.28	430	412	5.50	3.24	503	667	7.42	3.20	554	932	10.34	3.08	608	298	10.34
	1.57	4.86	477	216	3.85	4.68	573	441	5.50	4.51	690	706	10.24	4.44	805	1030	12.95	4.40	917	304	18.75
	2.09	5.61	573	235	7.69	5.35	690	451	10.34	5.24	843	706	16.13	5.04	978	942	16.13	4.86	1118	1187	17.44
	2.61	6.82	653	226	7.69	6.46	843	491	11.84	6.29	1048	775	13.33	6.05	1201	971	13.33	5.74	1383	1275	16.04
400	1.05	3.85	378	196	3.85	3.75	438	432	5.50	3.66	488	618	13.33	3.61	544	922	16.13	3.52	614	1187	17.44
	1.17	5.24	476	216	7.14	5.13	587	461	10.34	5.05	673	667	10.34	4.89	775	893	13.33	4.78	880	1216	14.73
	2.09	6.26	575	215	7.14	6.13	730	530	13.33	5.73	838	726	13.33	5.56	978	991	14.73	5.34	1128	1265	16.04
	2.61	7.39	676	275	7.69	7.15	873	530	13.33	7.06	1033	755	16.13	6.88	1194	1010	17.44	6.68	1389	1265	19.98

EFC - Effective field capacity; PC - Power consumption speed and working depth. Draft ranged from 137 to 863 N in the test.

As forward speed increased, effective field capacity increased. Slippage of wheel ranged from 3.85 to 18.75 per cent. As the depth of operation increased, wheel slip increased and effective field capacity decreased.

Power expended by the electric tiller with 300 mm sweep blade was 1223 W at 2.61 km h^{-1} forward speed at 100 mm operating depth. Power requirement indicated positive relationship with operating depth and forward speed. The maximum power requirements of 628, 786, 959 and 1253 W were observed at 1.05 , 1.57, 2.09 and 2.61 km h^{-1} forward speeds respectively. Draft had positive relationship with forward speed as well as with depth of operation. A peak draft of 1079 N was observed at operating depth of 100 mm while operating at 2.61 km h^{-1} forward speed.

The effective field capacity increased with respect to forward speed at all operating depths. The wheel slip ranged from 3.85 to 18.73 per cent during the test. The trend of the forward speed vs wheel slip curves changed with 300 mm sweep blade as compared to 200 and 250 mm sweep blades. With 300 mm sweep blade, the wheel slip decreased at all the depths of operation.

Power consumption possessed a positive linear relationship with forward speed at all operating depths tested. The variation of power consumption was from 373 to 1383 W and draft ranged from 196 to 1275 N in the test. Forward speed vs draft curves were almost flat at all depths of operation.

Effective field capacity had a positive relationship with forward speed and inverse relationship with operating depth. As the forward speed increased, the wheel slip increased in general at all depths of operation. As the depth of operation increased wheel slip increased.

The forward speed had a positive impact on power consumption in the case of 400 mm sweep blade at all operating speeds. The minimum and maximum power requirement of 378 and 1265 W respectively were observed. Draft did not change appreciably with increase in forward speed at all depths. Higher draft and higher forward speed resulted in higher power consumption. A peak draft of 1265 N at 2.61 km h^{-1} showed a peak power requirement of 1389 W.

As the forward speed increased, effective field capacity increased linearly. With 20 and 40 mm depths of operation, the wheel slip increased at a decreasing rate as the forward speed increased from 1.05 to 2.19 km h^{-1}. But with 60,80 and 100 mm depths, the wheel slip deceased at a decreasing rate. Wheel slip increased with increase in operating depth. The wheel slip ranged from 3.85 to 19.98 per cent.

The analysis revealed that a minimum wheel slip of 5.5 percent was obtained at 80 mm depth of operation, 1.05 km h^{-1} forward speed and 200 mm wide sweep blade.

The multiple linear regression analysis of the data revealed the following relationships.

a) Effective field capacity, $m^2\ h^{-1} = 214.1-0.687 D+157 F+1.272B$ ($R^2 = 0.95$)

b) Power consumption, $W= -372.5 + 4.917D + 303F + 0.75B$ ($R^2 = 0.93$)

c) Draft, $N= -588.6 + 10.25D + 57F + 1.549B$ ($R^2 = 0.95$)

d) Wheel slip, per cent $= -6.64 + 0.123D + 2.7F + 0.016B$ ($R^2 = 0.77$)

where D = Depth of operation, mm
F = Forward speed, km h^{-1} and
B = Blade width, mm

The electric powered tiller costs Rs.20,000/-. The operational cost of weeding and inter culture by the electric tiller was determined as Rs.450 ha^{-1} as compared to Rs.2000 ha^{-1} for manual method.

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