ABSTRACT

The present study was aimed to unite the advantages of powered discs and combination tillage together by developing a front active and rear passive set combined offset disc harrow (CODH) to efficiently handle the crop residues left after rice cultivation in lesser number of passes within limited available time. A laboratory prototype 3×3 CODH with each disc of diameter 510 mm and concavity 60 mm was developed and tested in the soil bin with sandy clay loam soil at a moisture content of 10±1% (db) to study the effects of speed ratio, u/v (2.4 to 3.6); front gang angle (25 to 40°); operating depth (100 to 140 mm); and soil cone index, CI (500±30 to 1100±30 kPa) on its draft, torque, and equivalent PTO power requirement (P_e). Tillage quality was assessed in terms of cone index of the tilled soil (CI_{tilled}). Its comparison was also made with the conventional free rolling offset disc harrow (ODH). From the soil bin investigations, the best system settings for CODH were found at front gang angle of 35º and u/v ratio of 3.6 in terms of minimum increase in estimated P_e and maximum reduction in CI_{tilled} compared to free rolling ODH at all tested soil conditions and operating depths. Using multiple regression technique, models were developed incorporating soil CI, front gang angle, operating depth, forward speed and u/v ratio from soil bin data to estimate the specific draft and torque requirements of CODH and specific draft requirement of free rolling ODH in sandy clay loam soil. Before developing a field prototype CODH, the developed models were used in genetic algorithm based multi-objective optimization to determine the optimum front gang angle and u/v ratio settings by minimizing the P_e and CI_{tilled}. These values were found to be varying in the range of 35.91º to 36.98º and 3.27 to 3.87, respectively.

A field prototype 6×6 CODH having each disc of diameter 560 mm, concavity 70 mm and total width of cut of 1.45 m was designed, developed and tested in the freshly harvested paddy fields (total paddy straw load of 4383 kg ha^{-1}) with sandy clay loam soil at a moisture content of 11±0.75% (db) and CI of 975±50 kPa using a 31 kW 2WD tractor. The power from the tractor PTO was transmitted to the input shaft of a suitable gearbox through a telescopic shaft, then to a set of universal joints, and ultimately through a side gear assembly to the front gang axle of the CODH. Tests were conducted at different forward speeds (3.46 to 6.82 km h^{-1}); rotational speeds of front gang axle, N_{FGA} (95 to 150 rpm); and operating depths (80 to 145 mm). The developed field prototype CODH outperformed the conventional free rolling ODH in terms of tillage performance index (TPI) comprising both energy required to carry out tillage and quality of soil tilth. In the field, the best performance of CODH in terms of TPI was obtained at forward speed of 4.55 km h^{-1} and N_{FGA} of 133 rpm corresponding to the u/v ratio of 3.09 during the first pass of tillage with a reduction in draft, slip, and clod size by 55.01%, 78.13%, and 37.41%, respectively as compared to free rolling ODH, whereas, P_e, fuel consumption (l ha^{-1}) and specific energy requirement were increased by 25.48%, 0.06%, and 4.07%, respectively. During the second pass, the best performance was obtained at forward speed of 3.46 km h^{-1} and N_{FGA} of 133 rpm corresponding to the u/v ratio of 4.06. The developed implement helped to achieve timeliness in seedbed preparation with better crop residue burial efficiency, improved soil tilth in lesser field passes, better penetration ability, reduction in draft, improvement in effective field capacity and better utilization of engine power of the tractor compared to free rolling ODH. Results provides a sound basis for using active-passive combination tillage implements for Indian farming system to improve the power utilization of tractors.

Keywords: Powered discs; Combination tillage; Sandy clay loam soil; Free rolling; Draft; Torque; Multi-objective optimization; Tillage performance index